

A Team-Based Approach to Studying Complex Healthcare Processes

Silis Yang Jiang

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## ABSTRACT

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Communication is a critical aspect of clinical work. In 2010, the Joint Commission (JC) found that gaps in communication were among leading factors contributing to medical errors.

Healthcare processes, such as patient discharge, depend on interdisciplinary communication to be successful. Electronic health records (EHRs) have the potential to facilitate communication and information sharing between interdisciplinary care team members; however, challenges remain in designing tools for team-based care and questions remain in understanding how EHRs impact interdisciplinary team communication. This dissertation focuses on understanding how EHRs can be designed to support communication and information sharing within interdisciplinary patient care teams. The first aim of the dissertation investigated how EHRs impact interdisciplinary clinical teams' communication, shared mental models, and information sharing activities. The results showed that implementing new EHR tools appeared to have little impact on communication and shared mental models, but new information sharing activities mediated by EHR developed. These changes and lack thereof suggest that new EHR tools will be specifically needed to facilitate interdisciplinary team information sharing activities. The second aim of the dissertation investigates the information sharing activities and information needs of interdisciplinary team members during patient discharge. The results showed that the information clinicians sought out during discharge depended on the roles that person played as

well as the progress of the discharge process. Future EHR tools should be aware of how patient care teams are progressing through the patient discharge process in order to provide information contextualized to their current tasks. In conclusion, interdisciplinary team communication and information sharing remain poorly supported by current EHRs and new tools designed specifically for interdisciplinary teams should provide information based on the completion of team activities.



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# Chapter 1: Introduction

## 1.1 Introduction

Healthcare delivery increasingly relies on interdisciplinary teams rather than the work of individual clinicians(1). Teams are groups of two or more individuals who interact towards a shared goal, and who have specific roles or functions (2). There is increasing evidence as to the positive impact of successful teamwork on patient care and outcomes(3-5). Additionally, *Studdert et al.* found that poor teamwork was attributable to 70% of adverse events(6).

Teamwork can be described by five different elements and three coordinating activities(7). The five elements are 1) team leadership, 2) mutual performance monitoring, 3) adaptability, 4) team orientation, and 5) backup behavior(7). Among these five elements, mutual performance monitoring, backup behavior, and adaptability describe the ability of members of a team to monitor each other's progress towards completing the teams' task, provide support when a team member needs help completing the task, and the ability to update team goals and individual tasks based on changes in the environment, respectively(7). Team leadership is the ability of an individual to direct others in the team, coordinate efforts between team members, and maintain a positive team atmosphere(7). Team orientation is an attitude among each individual team member that places greater importance on the goals and tasks of the team compared to the goals and tasks of the individual(7). The three coordinating activities are 1) communication, 2) shared mental models, and 3) mutual trust(7).

Among all of the elements and coordinating activities, communication is one of the most studied and important parts of teamwork in healthcare. Previous studies have examined effectiveness of

communication during various medical procedures, such as surgery and anesthesia(8,9). Many of these studies found an association between the quality of clinical communication and the quality of delivered care as well as patient outcomes. In fact, *Popovici et al.* found that “poor communication among clinicians is ubiquitously considered one of the main root causes of these adverse events.”(10)

While many healthcare processes require communication and teamwork, shift change clinical handoffs and patient discharge present particularly promising opportunities to study communication between clinical team members. Shift change clinical handoffs are the transfer of information and responsibility for patients between care providers. Patient discharge is the safe transition of patients out of the hospital setting(11). These processes have several important similarities, as well as differences. They are similar in that both rely heavily on communication, both have considerable impact on, and are in turn impacted by the quality of teamwork within patient care teams, and both have been shown to be susceptible to errors and gaps in communication(12,13). At the same time, there are several key differences between them. First, shift change clinical handoffs generally involve care providers in similar roles, such as resident physicians or nurses, whereas patient discharge requires interdisciplinary teams(14). Second, while handoffs occur frequently and within discrete periods of time, patient discharge is a continuous process that typically occurs over several hours or days. Third, while shift change handoffs typically involve a single conversation supported by documentation, patient discharge may involve multiple steps and subtasks. Lastly, many EHR tools have been developed to facilitate clinical handoffs, but relatively fewer EHR tools target improvement in patient discharge. In summary, these two processes provide complementary opportunities to study communication

within patient teams and opportunities to support it with novel informatics solutions, particularly those embedded within Electronic Health Records (EHRs).

EHRs became widely implemented during the late 2000's with the goal of facilitating clinical work, along with many other healthcare related activities, such as billing(15). Previous research suggested that implementing EHRs has had both positive and negative effects of clinical work. Some studies have shown that EHRs or components of EHRs have reduced rates of medical errors(16), adverse events(17), and wrong medication orders(18). Well-designed EHR tools have also helped clinicians develop a better understanding of their patients (19) (20). However, together with these improvements in quality and safety, other studies showed reductions in productivity(21), decreased time with patients(22,23), as well as negative impact on patient outcomes(24). Some researchers have demonstrated that usability issues and poor EHR interface design led to these negative consequences(21,25,26).

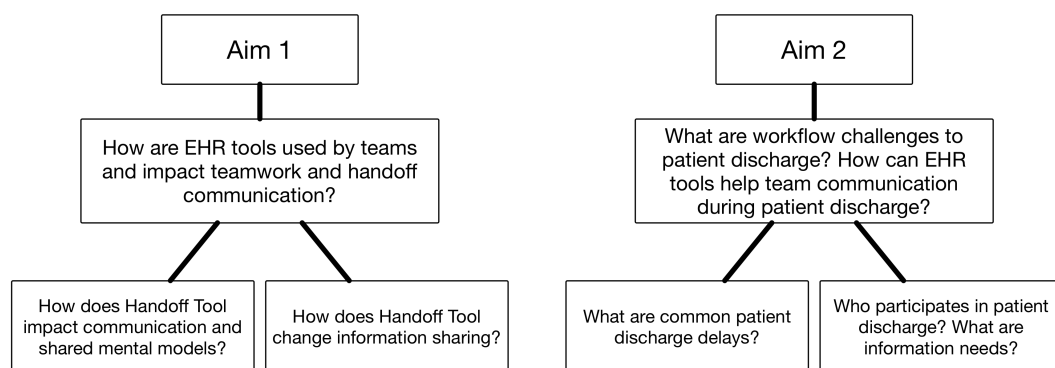
In addition to studying these broad effects of EHR on care delivery, previous research has examined the impact of EHR on provider-provider communication. Two ways EHRs facilitate provider-to-provider communication, either synchronously or asynchronously, is through either messaging tools or documentation. In a review, *Walsh et al.* found increasing prevalence of direct messaging tools as part of EHRs; however, these authors also noted that these tools were primarily used for communication between members of the same discipline, namely physicians to physicians(27).

Until recently, few studies of electronic documentation tools explicitly examined their potential as a mechanism for facilitating interdisciplinary communication. Recently though, electronic handoff documentation tools have been shown to be increasingly adopted by clinicians other

than their intended users (most commonly resident physicians) and used to transmit information between different members of patient teams (28,29). The plausibility of electronic handoff tools as a mechanism for interdisciplinary communication is further supported by studies of handoff documentation structure(30) and content overlap(31), which showed considerable overlaps in information included in the handoffs of clinicians in different roles. These studies demonstrate that EHRs, and in particular handoff documentation tools(28,29,32), can be used to help clinicians share information with interdisciplinary team members. While information sharing is not equivalent to communication, it does represent one important part of communication. Information sharing is passing of information from one person to another(7); a typical example of information sharing in clinical work is through documentation, wherein clinicians share information regarding patients and their care with others by recording it in their notes. Communication, on the other hand, is a cycle where one person shares information and a second person demonstrates an understanding of that information or makes contribution of their own, thereby closing the loop of communication(33,34). Communication could occur both synchronously (as in a verbal handoff discussion) or asynchronously (for example through direct messaging), but in either case it implies involvement and contribution of both parties. While some authors specifically characterize this phenomenon as close-loop communication, many others consider it to be a more general and necessary property of any communication. Importantly, many questions still remain in understanding how EHRs can support either information sharing or closed-loop communication. Among these are: what are the important patterns of interdisciplinary communication that accompany such processes as shift end handoff and patient discharge; how do EHRs change communication and information sharing practices

between care team members; and how can electronic tools be better designed with interdisciplinary communication in mind, rather than as an unexpected secondary use as happened with electronic handoff tools.

The general goal of this dissertation is to further explore how interdisciplinary teams perform work in the clinical setting, and how EHRs impact communication and work within interdisciplinary patient care teams. With the rise of EHRs in the clinical workplace, understanding the interplay between interdisciplinary teams, their work, and the tools that support their work is crucial. There are two principle aims in this dissertation (Figure 1.1). The first aim focuses on understanding how EHRs, and in particular electronic documentation tools, impact communication and coordination within interdisciplinary patient care teams that occur during shift handoff. The second aim focuses on understanding interdisciplinary clinical work processes, with the specific focus on discharge planning, and on ways HIT tools can facilitate interdisciplinary clinical work.



**Figure 1.1.** *Overall description of dissertation research questions by aims*

## 1.2 Aim I

Broadly, the goal of this aim was to understand how interdisciplinary patient teams communicate during transitions of care and how HIT impacts this communication. In particular, this aim focused on evaluating the impact of electronic handoff tools on how clinical team members communicate during shift change handoffs, both from a single discipline and interdisciplinary perspective. Clinical handoffs represent a particularly valuable area of study because clinical handoffs impact clinicians' understanding of their patients(35) and can have an impact on coordination within patient care teams(36). Moreover, due to the wide adoption of electronic handoff tools, they present a unique opportunity to study the impact of HIT on communication within teams. Clinical handoffs are the transfer of information and responsibility for one or more patients between two or more clinicians during shift change, transfer to another unit, or other transitions of care(33). Clinical handoffs can take several different forms(33); however, shift change clinical handoffs often occur through in-person verbal communication (37), (38). A previous study by the Joint Commission found that 80% of adverse events results from miscommunication during patient handoffs(39). To compound this issue, clinical handoffs have become even more prevalent after new work hour restrictions were implemented for resident physicians(37) and nurses(40). To improve clinical handoffs, many interventions have been implemented. These interventions can be placed into a few broad categories, such as training, workflow changes, and new EHR tools. Several interventions introduced thus far that included EHR tools showed varying effects on decreasing harm to patient because of handoffs; however, few intervention evaluations have focused on how these tools affected the verbal handoff itself. Similarly, few studies have

examined how electronic handoff tools impacted information seeking or information sharing behaviors. In this aim, I sought to understand the impact of an electronic handoff tool, locally referred to as the Handoff Tool, on team communication, patient understanding, and information sharing and seeking behaviors (Table 1.1). The Handoff Tool was developed by local experts at NewYork-Presbyterian Hospital to help residents document pertinent information during clinical handoffs using user-centered design(32).



*Table 1.1 Overview of Aim I studies*

<b>Project</b>	<b>Outcome Measure</b>	<b>Hypothesis/Research Question</b>	<b>Data</b>
1.1 Handoff Conversation	(1) Interactivity (2) Question Asking	H1: Implementation of the Handoff Tool impacts conversation interactivity and rate questions are asked during verbal handoffs	145 verbal handoffs (65 pre-, 80 post-) of PICU fellows, residents, and nurses
1.2 Shared Mental Models during Handoff	(1) Content Overlap (2) Discrepancies	H2: Implementation of the Handoff Tool impacts shared mental models within patient care teams as measured by content overlap and discrepancies between verbal handoffs of clinicians on patient care teams	50 verbal handoff groups (21 pre-, 29 post-) of PICU fellows, residents, and nurses
2. Information Sharing Practices Using Handoff Tool	Frequency of the Handoff Tool updates and views	Q1: When do clinicians write handoff notes? Q2: Who reads these notes, and when are they read?	Audit log of Handoff Tool for CUMC/NYP October 2013, 7 interviews with clinicians from various hospital service lines

The first aim focused on analyzing the impact of the Handoff Tool implementation on different aspects of clinical teamwork, such as changes in patterns of communication and shared mental models (SMMs) in the pediatric intensive care unit (PICU). The impact of the Handoff Tool on communication was measured by comparing the rate of conversation interactivity and frequency of questions asked during individual handoffs before and after implementation. The impact of the Handoff Tool on SMMs was measured by comparing the degree of content overlap between individual handoffs of team members before and after the tool's implementation.

The second study was a two-part study that investigated how the Handoff Tool changed the workflow practices around 1) documentation and 2) information sharing using a mixture of audit logs and interviews with clinicians from various clinical departments and roles. The audit log of all the Handoff Tool usage throughout Columbia University Medical Center for October 2013 was collected. The counts of every update and view made to each patient handoff note were tabulated, and an analysis was performed to identify relationships between the frequency with which notes were edited and viewed. Seven clinicians from 3 different clinical settings were interviewed. The interviews centered on identifying documentation behaviors and use of the Handoff Tool to share information among other team members.

### 1.3 Aim II

The goal of this aim was to understand how HIT can be designed to support interdisciplinary communication and information sharing. Prior work in Aim I demonstrated a need for HIT to facilitate information sharing during complex, interdisciplinary care processes. In this aim, I focused on understanding and characterizing the clinical workflow, information needs, and information sharing during patient discharge with the goals of guiding the development of future informatics solutions to support information sharing among interdisciplinary teams during patient discharge.

Patient discharge is the safe transition of patients out of the hospital setting; previous research argued that discharge planning should start immediately following an admission and should continue throughout patient stay(12). Discharge is a complex process; it includes multiple steps, such as planning and executing the different activities necessary for safe transition of patients, identifying and addressing critical post-acute care challenges, and educating the patient and

family of new medical needs. Moreover, multiple studies suggested that successful discharge requires coordinated effort of multiple providers. For instance, physicians focus on stabilizing or returning patients to baseline, while social workers and care coordinators facilitate the transition out of the hospital, and nurses provide education regarding post-discharge care to patients and their family members. Unfortunately, delays occur frequently in the discharge process, which can increase patients' length of stay (LOS), and associated frequency of hospital-acquired infections(41). A study at a level 1 trauma center showed discharge delays incurred an additional \$2.52 million per year in costs(42). Previous analysis of discharge delays has shown that many patient characteristics or health conditions, such as being older, co-morbidities, dementia, insurance status, and more, lead to an increased chance of experiencing discharge delays(42-45). While understanding patient characteristics that present risk factors for discharge delays is crucial in balancing resource utilization to reduce delays, there remains many questions as to what changes to discharge workflows and what tools can help to prevent discharge delays. For instance, few studies have investigated characteristics of communication and teamwork that are associated with discharge delays, and why high-risk patients complicate the discharge process. Furthermore, HIT vendor solutions appear to be inadequate in supporting team information sharing related to discharge. Therefore, the goal of this aim was to characterize the discharge process by identifying information needs from the perspective of clinician in different roles during different stages of the discharge process and investigating and categorizing common discharge delays. The goal of these projects was to develop an understanding of the current gaps in information sharing as well as barriers to discharging patients in a timely manner as well as to

propose informatics solutions that can improve team communication and information sharing in the context of patient discharge (Table 1.2).

*Table 1.2 Overview of Aim II studies*

Project	Research Questions	Data
3.1 Qualitative Analysis of Patient Discharge Process	Who participates in patient discharge? What are functions and information needs of different clinicians involved in discharge planning and execution? What barriers do they perceive to the patient discharge process?	Semi-structured interviews with 3 residents, 3 bedside nurses, 2 attending physicians, 2 care coordinators, and 2 social workers.
3.2 Quantitative Analysis of Patient Discharge Process	What are information-seeking practices of care team members in the 24 hours preceding patient discharge? How do these practices change over time? Are there differences in information seeking behaviors of clinicians respective to different patients?	Audit logs for (nearly) all actions in iNYP and Eclipsys for patients discharged from M5GS between January 2016 to June 2016
4. Discharge Delay Classification	What dimensions describe discharge delays?	All discharge delays documented for Milstein and Allen Hospitals between January 2015 through September 2015.

In this aim, I sought to understand and characterize information needs during a typical discharge workflow. I also studied common discharge delays, and how these delays could be related to deficiencies in fulfilling information needs by clinicians. The first study in this aim focused on understanding coordination and information sharing during the discharge process using a mixed-methods approach. I conducted interviews with various care team members, including physicians in different roles (residents and attending physicians), care coordinators, social workers, and

bedside nurses to identify 1) their respective roles during the discharge process, 2) their information needs on different phases of the discharge process and 3) their perceptions regarding barriers to successful discharge from their role-specific perspective. The transcripts of these interviews were inductively coded and main themes were identified.

To understand clinicians' information needs and trajectory of these needs during the discharge process, I used audit logs that captured what information clinicians access in the hours leading to discharge. Using audit logs, I mapped out the evolution of information needs met through the use of EHR during the last 24 hours of a patient's hospital stay. Additionally, I identified significant associations between clinicians' use of the EHR and patients' length of stay using linear regression. The second study of this aim investigated how free-form comments describing discharge delays could be used to develop a classification of discharge delays. Over 5500 discharge delay notes from Columbia University Medical Center/NewYork-Presbyterian Hospital (CUMC/NYPH) adult care units were collected over a period of 9 months between January and September of 2015. Two hundred discharge delay notes were randomly selected. An interdisciplinary team consisting of two informaticians and a nurse-researcher qualitatively reviewed these notes and developed a classification of discharge delays. The classification was evaluated using a new set of one hundred randomly selected discharge delay notes by an informaticians and a different nurse-researcher.

## 1.4 Significance and Contributions

The work in this dissertation contributes to the understanding of 1) current practices related to teamwork, communication, and information sharing, particularly during shift-end handoffs and during patient discharge, 2) information needs of interdisciplinary team members during patient

discharge, and 3) new opportunities to use EHRs to facilitate these processes. This dissertation also makes a methodological contribution in exploring ways to use EHR usage logs to study patterns of clinical communication and information needs.

The findings of Aim I showed that clinical teams frequently rely on electronic tools to support interdisciplinary communication. Existing EHR tools can be repurposed to facilitate teamwork and communication; however these tools appear to have a limited effect on teamwork measures. These findings suggest a need for tools that specifically focus on promoting interdisciplinary communication.

The findings of Aim II demonstrated that interdisciplinary team members have shared information needs that evolve over the course of a patient discharge. Therefore tools for supporting information sharing need to help clinicians maintain awareness of their discipline-specific priorities, while at the same time exposing them to priorities of other clinicians on the team. Moreover, these tools need to be sensitive to the trajectory of discharge planning and execution in order to display the right information at the right time to the right person.

Methodologically, I have demonstrated that usage log analysis can be a useful method for studying clinical information sharing and information needs; however, these methods need to be complemented with more traditional qualitative study approaches. For instance, in Aim II, qualitative interviews identified many unmet information needs, while audit logs showed what information was accessed in the EHR prior to patient discharge. The use of only one method to study information needs would have missed out on the key findings of Aim II. Future studies on information needs should use multiple data sources and different analytical approaches to triangulate different findings.

## 1.5 Limitations

This dissertation has a number of limitations. First, this dissertation took place within a single academic medical center, and several studies included in this dissertation were conducted within a single unit. Thus some results may not generalize to other units within the academic medical center or to other academic medical centers. Second, while audit logs are a valuable source of information for understanding clinical work and information needs, audit logs can only capture a portion of all work and information needs. Therefore, findings about information needs or work practices may be incomplete or misrepresented by audit logs. Third, there was extensive use of qualitative analysis of data, which often relied on subjective interpretation of observers. For instance, much of the qualitative data involved technical clinical jargon, which may have been misinterpreted by the research team. Furthermore, qualitative coding of both the clinical handoffs and discharge delays is subject to the bias of coders. Qualitative coding is intensive, manual work, and therefore subject to issues such as concentration and the working memory of the research team.

## Chapter 2: Literature Review

### 2.1 Introduction

In recent decades, healthcare delivery has become increasingly recognized as a team-based activity rather than that of a single clinician or even single care discipline(46). Physicians, nurses, social workers, physical therapists, and many others must work together to ensure high-quality care is delivered. Many previous studies have highlighted associations between interdisciplinary teams and improved patient outcomes(5) and have specifically linked clinicians ability to work together with improved patient outcomes(3,4). Teamwork has five essential elements, and three coordinating activities(7). The five essential elements are team leadership, mutual performance monitoring, backup behavior, adaptability, and team orientation, which are maintained by the three coordinating activities, communication, shared mental models, and mutual trust(7).

Among these eight aspects of teamwork, communication, arguably, has received the most attention from the research community. While there are many definitions and classifications of communication, many previous authors refer to “closed-loop” communication. Closed-loop communication is a mode of communication where both parties in a transmission verify that the information has been received and interpreted correctly(34). This type of communication is particularly important in medicine, especially during high risk periods, such as in emergency medicine, as it reduces risk of communication breakdowns(34). Improved clinical communication has been the goal of many interventions(47-49). One of the earliest reports on communication and patient outcomes found that miscommunication was the leading cause of medical errors(50). In response, many interventions have been introduced to improve the quality of communication and reduce patient harm(48,51). Breaks in communication affect many aspects of clinical work;



however, they are particularly impactful when they occur during handoff and as part of patient discharge. A handoff is the transfer of information and responsibility for patient care during shift change or other transitions in patient care (52). Patient discharge is the process of moving patients out of the hospital setting(11). Both of these processes present complementary opportunities to study communication and coordination within interdisciplinary teams and ways to support it with informatics interventions.

Electronic health records (EHRs) play a major part of each individual team member's clinical work. EHRs are now a part of 96% hospitals(53). Previous studies of EHR implementation documented both its positive and negative impact on clinical work and patient outcomes. For instance, *Planteir et al.* found that adoption of EHRs in France lead to improved quality of care across the country(54). However, at the same time, poor implementation has led to increased clinician documentation time(22,55), significant changes to workflow(26), and increased patient mortality(24). Despite continuing improvement in the functionality and usability of contemporary EHR systems, one critical limitation continues to be lack of explicit support for interdisciplinary teamwork and communication(29). Despite the importance of teamwork, communication, and coordination in clinical care, EHRs continue to focus on supporting individual providers rather than interdisciplinary teams. Moreover, with few exceptions, documentation of clinical information is captured as a single-provider note, for example nursing progress notes or resident handoff notes. Different studies have shown that implementation of EHRs have led to increased documentation variability(56), and more information silos(23). These side effects of EHR implementation have challenged clinicians' ability to communicate efficiently and increased cognitive load(56).

## 2.2 Introduction of research gaps

The focus of this dissertation is on identifying new opportunities to support interdisciplinary communication with novel informatics solutions. While there have been significant advances in applying informatics solutions to providing clinical decision-support, there remains considerable gaps in our understanding of interdisciplinary communication and in identifying of new solutions for promoting it. Previous research has identified two distinct approaches to using EHRs for facilitating communication and information sharing within interdisciplinary care teams: documentation and direct messaging tools. *Walsh et al.* found that direct messaging tools were useful for communicating between providers of the same role; however there has been no reported use of direct messaging tools in the EHR for non-physician care providers(27). On the other hand, there is a growing body of evidence suggesting the importance of electronic documentation tools for facilitating interdisciplinary communication.

A new class of documentation tools, collectively called electronic handoff tools, has been gaining popularity among a variety of healthcare professionals(28,29,32). These tools, which are typically designed to support single-role transitions of care (most commonly residents or nurses), have been shown to be used by clinicians other than their original intended users. For example, studies of handoff tools designed to support transitions of care among resident physicians showed that these tools were actively used by nurses(28,32) and physical therapists(29) who used it to gather medical information about patients in a more efficient way than reading the entire corpus of available documentation(29). However, these early studies of unintended use of electronic handoff tools also noted that information in the residents' handoff notes fell short of meeting all information needs of clinicians in other roles(28,29).

Related to exploring information needs among interdisciplinary team members, *Collins et al.* found that there is a high concordance in the categories of information documented in handoff notes between physicians and nurses; however, this study was conducted on paper-based rather than electronic handoff documentation(30).

In summary, few studies conducted thus far have specifically examined information needs of members of interdisciplinary patient care teams that arise during handoff or during patient discharge and how these needs can be met with new informatics solutions. The goal of this dissertation is to address this gap by developing rich understanding of patterns of communication and information sharing within interdisciplinary patient care teams, particularly in the context of handoff and patient discharge, and to outline initial directions for the design of new solutions for promoting these processes.

## 2.3 Teamwork in healthcare

### 2.3.1 Background of teamwork properties

Teamwork has been extensively studied both within and outside of healthcare. While many elements of teamwork have been identified, 5 basic elements all teams need in order to be successful are team leadership, mutual performance monitoring, backup behavior, adaptability, and team orientation{Salas, 2005}. Team leadership is the ability for an individual to command and coordinate others on the team, along with developing and maintaining a positive team atmosphere{Salas, 2005}. Mutual performance monitoring is the ability for team members to develop an understanding of and monitor others' task performance{Salas, 2005}. Backup behavior is the ability for team members to anticipate team member needs and act to address those needs{Salas, 2005}. Adaptability is the ability to adjust the strategy of the team based on

the changing environment. Team orientation is the ability to consider the attitude of others on the team and give preference for the goals of the team rather than individual{Salas, 2005}. In order to maintain these elements, teams must have 3 coordinating activities: closed-loop communication, shared mental models, and mutual trust(7). Closed communication is an exchange of information between two team members, regardless of how that exchange occurs, with opportunities to ensure that the information exchanged has been properly interpreted(34). Conversely, information can be passed between two team members without confirmation that the information has been correctly interpreted or even received(7). In this dissertation this type of information exchange will be referred to as information sharing. Based on this definition, communication in this dissertation refers to both in person information sharing and passing information through other media, such as in clinical documentation. Shared mental models is the knowledge of the tasks the team must perform and how team members are expected to interact with one another(7). Mutual trust is the belief among team members that individuals will perform the tasks assigned to their role(7).

Studies of teamwork in clinical care have shown that several of these different elements and coordinating activities have been implicated in process measures or patient outcomes. *Studdert et al.* found that poor teamwork was associated with 70% of adverse events(6). *Husebø et al.* found that leadership skills interventions improved patient outcomes in stroke units(57). *Page et al.* found that establishing stronger shared mental models could improve continuity of care between inpatient and outpatient oncology settings(58). *Stepaniak et al.* found shorter surgical procedure durations and higher perceptions of teamwork and safety when surgical teams

remained consistent throughout the day(59). *Raymond et al.* found that improving the quality of communication increased the quality and safety of patient care(60).

### **2.3.2. Communication in Healthcare**

Communication, in particular, has been extensively studied in the context of medicine. Miscommunication during handoff communication is attributed to 80% of serious medical errors(6). These studies motivated many interventions to improve communication in hopes to improve patient safety and care quality. For instance, *Malpass et al.* found a communication intervention that standardized communication during non-ICU to ICU transfers led to fewer central venous catheter infections, as well as changes to antibiotic orders after being admitted to the ICU(61). A few studies have focused on developing better shared understanding(58) or standardizing documentation patterns(62) to reduce gaps in communication between inpatient and outpatient providers. During patient discharge, gaps in communication between inpatient and outpatient care teams pose a significant challenge in care continuity for patients(58). However, these studies are focused on single-discipline communication, rather than interdisciplinary communication.

In previous studies of interdisciplinary teamwork and communication, many challenges to interdisciplinary work and communication have been noted(46,63). In the context of delivering clinical care in general, *Lancaster et al.* and *Stein-Parbury et al.* both found breakdowns in interdisciplinary communication due to differences in priorities of different care provider roles, such as physicians and nurses(49,64). Another challenge of interdisciplinary team communication is the rarity with which it happens(49). Others have reported that lack of training on teamwork and interdisciplinary communication during educational periods limit the understanding and

contributions of interdisciplinary team members as well(65) and leave trainees unprepared to work in interdisciplinary teams(66). To address these challenges, many interventions have been performed. Training and education, for instance, has been demonstrated to be successful at improving perceptions of teamwork and teamwork performance. *Brock et al.*, *Cleak et al.*, and *Mu et al.* all found that performing interdisciplinary exercises during professional schools, i.e. medical school, nursing school, and physical therapy school, improved perceptions of interdisciplinary teamwork and attitudes towards interdisciplinary communication(66-68). In a review paper, *Fung et al.* found 2 studies (out of 12 studies) that demonstrated improved patient outcomes and 1 study demonstrating improved teamwork skills after professionals were given crisis management training simulation(69).

## 2.4 Communication Dependent Healthcare Processes

### 2.4.1 Shift-change handoffs

Clinical handoffs are the transfer of information about and responsibilities for patients between two or more care providers(52). These handoffs are critical to continuity of care(70). They can be accompanied by verbal communication, or through documentation(71). Usually handoffs take place between just two providers of the same clinical experience level(52), but sometimes are incorporated into teaching rounds(72).

Communication, especially interactive conversations, during shift change serve as a basis for care team members to develop an understanding of the patient for the next shift(35,73). Poor communication during clinical handoffs lead to adverse events(74,75)[Sorrentino, P; Use of Failure Mode and Effects Analysis to Improve Emergency Department Handoff Processes] and leads to the potential for misinformation to be propagated through later clinical handoffs(72).

Poor communication occurs frequently during handoffs because of the complexity of the communication process(73). Verbal handoffs occur during a short amount of time, with potentially little to no follow-up(35) and information transferred changes in each handoff. Despite these concerns, shift change handoffs have increased during the last 15 years because of policy changes restricting the number of consecutive work hours for residents, particularly interns, and nurses(76,77). The combination of the complexity of handoff communication along with increased frequency of handoffs occurring makes studying handoff and improving handoff of particular importance.

#### **2.4.2 Interventions on Clinical Handoffs**

In order to address these challenges, many interventions have been conducted to improve interdisciplinary communication. In general, these interventions can be placed into four non-exclusive classes: 1) process redesign, 2) training and education, 3) standardization of communication, and 4) health IT tools, particularly EHR based. Some studies have focused on improving clinical handoffs through a single intervention type, such as focusing on just training and education, while others have focused on combining several or all types of interventions.

##### *2.4.2.1 Process-change interventions*

There have been a number of process redesign initiatives aimed at improving handoffs. Many of these handoff interventions have been developed for local environments(78) (79). Some process redesign initiatives include goals to standardize communication using mnemonics. The intervention for many of these projects are developed by using different process redesign frameworks, such as failure mode and effect analysis (FMEA) (80), appreciative inquiry(78), and plan-do-study-act (PDSA) (79). Similarly, there is a mixture of outcomes reported which can be

classified into four categories: clinician perceptions towards handoff(79,81,82), patient satisfaction(79,82), patient outcomes(16,83), and handoff quality and duration(79).

However, process redesign studies of handoff are limited in a few ways. First, most process redesign studies offer solutions that are highly customized and designed to specifically address local concerns, which limits the generalizability of the interventions that were used(80,81).

However, a few process redesign interventions were evaluated in multicenter environments, which demonstrates the possibility that these types of interventions can be brought to other settings(82). Another limitation of process redesign interventions is that while many of these interventions involved interdisciplinary clinical teams, evaluations focused only on the handoffs of a particular care provider type, primarily resident (medical) or nursing(79,81,82). Comparatively, very few evaluations of process redesign interventions have focused on shared understanding or other teamwork measures took place. Lastly, many of these studies used a simple pre-/post- study design in evaluating improvements(80,81) , and some studies simply reported changes to outcome measures without statistical analysis(79). Very few studies that redesigned the handoff process used experimental study designs, such as randomized controlled trials(16). This trend suggests that most process redesign interventions appear to have low study design rigor, which presents another challenge to generalizability.

#### *2.3.2.2 Training and education*

Following increased awareness of challenges in performing handoff, formal education and training to support handoff began. Formal education in the classroom for medical students(84,85) and residents(86) were developed and implemented. Shorter term and less formal training were also incorporated for residents and nurses(37,87). The content covered in handoff training



various but frequently contains handoff mnemonics as well as explanations on the importance of communication in preventing adverse events and other relevant information and learning what good communication consists of(87).

These education and training initiatives have been measured in a variety of ways, but the two most predominate ways are surveys and assessments of mock verbal handoffs following a training course(87). Overall, education and training improved adherence to handoff protocol(86) and produced sustained improvements in handoffs quality(85,88). However, despite the utility of training and preparing medical students and residents for handoff, there continue to be deficiencies in the pervasiveness of handoff training and education. Several national surveys have found that while handoff training has increased, it is still not universally taught(86,87,89).

#### *2.4.2.3 Standardization*

Standardization is another popular method used to improve handoffs, and it is a central part of the Joint Commission's recommendations to improve handoff communication. A systematic review found that more than 20 different mnemonics have been implemented in hopes of improving handoffs(90). Among these different types, SBAR and iPASS were the most widely implemented(90). Both of these mnemonics are also notable because they have been implemented in large institutions or as part of large trials(47,48). Several major studies evaluating standardization have reported on handoff improvement interventions that include standardization as just one part of the improvement process(16). In general these interventions have proven to be successful in improving different measures of handoff, such as completeness of handoff information(91) and reduction in adverse events(92).

While multi-component interventions that included mnemonics have been widely studied, a few have evaluations handoff standardization and mnemonics in isolation. These studies found that there is great variation in the types of information included in mnemonic, and no single mnemonic provided comprehensive coverage of handoff related communication (93) . Use of mnemonics have been evaluated both in terms of efficacy in improving patient outcomes and perceived usefulness. The efficacy of mnemonics in improving handoff communication was frequently assessed using self-report data, such as questionnaires and surveys (82) . Generally, interventions have increased the perceived quality of handoff communication(94). However, other studies have found that recall in information discussed during verbal handoffs was lower after implementing a mnemonic(95) .

While mnemonics have been widely implemented, some researchers have argued the limitations of relying on mnemonics and checklists to improve handoff communication. For instance, *Cohen et al.* contended that interactive conversations were crucial in team members developing a shared understanding of the patient during handoffs, and that mnemonics and standardization may not help in prompting these interactive conversations(35). *Hilligoss et al.* expanded further, suggesting that the complexity of verbal handoffs requires more focus on improving communication elements, such as conversation interactivity, rather than just standardizing handoffs(73,96). However, much of the literature on this topic are based on viewpoints, rather than empiric research. Thus, it seems that further empiric research on how handoff interventions, and especially mnemonics, impact conversation elements are needed.

#### 2.4.2.4 Electronic Handoff tools

Electronic handoff tools have become widely adopted by many healthcare systems, and they have also been evaluated for their impact on improving patient outcomes(16,17), reducing handoff durations, and improving completeness of their verbal or written handoff(97). In addition to measuring the impact of these tools on handoff related outcomes, several studies have identified the unintended use of such electronic tools by non-intended user groups. While most handoff tools are targeted at either residents(52) or nurses(98), *Campion et al.*, *Schuster et al.*, and *Vawdrey et al.* have all identified electronic handoff tool use by targeted and non-targeted care team members(28,29,32). *Campion et al.* found nurses and care managers using a resident focused electronic handoff tool(28), while *Schuster et al.* found physical therapists and social workers incorporating an electronic resident handoff tool as a key source of information(29). *Vawdrey et al.* identified a high frequency of tool usage among nurses suggesting a tight integration of a resident handoff tool into nursing workflow despite no abilities for nurses the edit notes in the electronic handoff tool(32).

The potential of electronic handoff tools to facilitate teamwork, communication, and information sharing, especially as highlighted by these early studies, is intriguing. These early studies suggest that further studies that focus on understanding how teams use electronic handoff tools and the limitations of these tools in facilitating clinical teamwork are vital to understanding how future electronic tools can facilitate interdisciplinary team communication and information sharing. Research participants reported an eagerness to incorporate interdisciplinary information as information sources for their clinical work, and EHR-based tools can be a great platform to facilitate this exchange of information(28,29).

### **2.4.3 Gaps in current knowledge regarding the impact of IT tools on clinical handoff**

Despite the untapped potential, much more still needs to be understood about electronic handoff tools in relation to team-based communication. There is still little known about how these tools affect the nature of communication outside of standardizing how information is presented. Most studies, even those on standardizing communication, have focused on either patient outcomes, healthcare processes, or the completeness of the verbal or written report. Few studies have focused on how interventions focused on improving handoff communications have changed how team members converse with one another, how these tools affect team members' critical ability to develop a shared understanding of the patient during handoffs. Furthermore, studies of intended use of electronic handoff tools have yet to describe what workflow changes were necessary to allow for these tools to be used in a new way.

## **2.4 Patient discharge**

The challenges of interdisciplinary communication, which were highlighted earlier, present unique difficulties during the patient discharge process. *Bergstrom et al.* found that 8.8% of discharge plans were not fully communicated between interdisciplinary team members(12). Furthermore, physicians and nurses have different opinions on which elements of the discharge plan to prioritize(99). *Lin et al.* found many constraints and competing priorities during the discharge process(100).

Like interdisciplinary communication in general and clinical handoffs, there have been several classes of interventions to improve interdisciplinary communication during the patient discharge process. There have been many process redesign interventions aimed at improving interdisciplinary communication, particularly for patient discharge. One type of solutions for

process redesign of interdisciplinary communication during patient discharge is introduction of interdisciplinary rounds (IDR), which aim to give interdisciplinary team members dedicated time for communication regarding discharge. Implementing IDR has been associated with increased patient satisfaction(101,102), on-time patient discharge(103), and improved patient safety(102,104-107). Another approach to improving interdisciplinary communication is to introduce new members into the discharge team workflow. For instance, adding pharmacist during discharge improved the medication reconciliation rate(108,109). Redistribution of tasks, as in the past two studies, spreads out the team tasks based on expertise and provides new opportunities for information to flow through the team(110). Efforts for standardizing communication, for example through SBAR, between care team members during IDR have also proven effective in improving situation awareness and patient satisfaction(101), increasing guideline adherence and readmission rates(111).

#### *2.4.1 Breaks in discharge process can cause discharge delays*

Patient discharge is defined as a safe transition of patients from the hospital to a post-acute setting, such as home or nursing home(11). Patient discharge is strongly dependent on interdisciplinary communication and teamwork(14). Adding to the challenges of interdisciplinary teamwork, patient discharge consists of many steps that must be executed before a patient can be safely discharged from the hospital.

A frequent measure associated with patient discharge is discharge delays. Almost all definitions refer to discharge delays as an extended period of time a patient remains in the hospital after being medically cleared for discharge(42,112,113). However, whereas some studies refer to discharge delays measured in hours(113), other measure delays in days(42,112). Discharge delays

are a critical measure of discharge success because of the impact of discharge delays on patients and hospitals. Patients suffer because of increased length of stay, which is associated with increased risk for hospital-acquired infections(41). Hospitals incur great costs and have breaks in patient flow(42). Unfortunately, delays also happen frequently. Previous studies on the frequency of discharge delays found as few as 4% discharge delays to as frequently as 50%; however, most studies found that discharge delays ranged between 25% to 40%(43,44,114,115). Because of the importance of discharge delays, there have been several studies that examined different causes for discharge delays. Many studies connected discharge delays with specific patient characteristics, for example old age (43); others related discharge delays to characteristics of the discharge process, for example discharges late in the day(116,117).

#### **2.4.2 Interventions to reduce discharge delays**

There have been many team-based inventions to reduce discharge delays and to improve the discharge process in general. In many of these interventions, a process redesign takes place that adds additional interdisciplinary team members or redistributes the tasks of each interdisciplinary team member. This strategy has been helpful for a number of different patient types, such as psychiatric patients(118), neurosurgery patients(119), and internal medicine ward patients(120). By far, the most frequently used metric to evaluate improvements in of process improvement interventions are 30-day readmission rates. Re-Engineered Discharge (RED), an AHRQ sponsored program, was shown reduced hospital utilization by 30% in a 30-day period(121). However, similar to process redesign interventions to improve handoff, very few process redesign projects are evaluated in a multi-setting or multisite design.

## 2.5 Methods of studying work processes

An important element to studying clinical processes is the method or methods used in the research study. Understanding the clinical process is a critical part for both developing and evaluation. Solutions in healthcare need to be tailored for the local work environment; and one step towards tailoring the solution is studying the clinical process the solution will be integrated into. Generally, there are three high-level approaches to study clinical work processes: qualitative, quantitative, and mixed-methods studies, all of which have their own advantages and disadvantages.

### 2.5.1 Qualitative Methods

There are many qualitative methods to study clinical work and workplaces in general. These can be placed into several different classes, including ethnographic observations, interviews and focus groups, and more.

Ethnography is the application of ethnographic data-gathering and theory-driven data analysis without preconceptions or insider bias(122). Ethnography is used in many fields related to biomedical informatics, such as computer-supported cooperative work (CSCW) and software design, but has only become widely used in biomedical informatics in the last 15 years. While ethnographic methods can include many data collection techniques(122), such as observations, interviews, and video and audio recordings of work, many ethnographic studies in biomedical informatics primarily focus on observational methods(123). Ethnography has become a centerpiece of research methodology for clinical work because it allows researchers to develop a deep understanding of clinical process and the interaction between systems, whether the systems involve people or IT solutions(122,124). For instance, *May et al.* used ethnography to

described the rich interaction between psychiatric healthcare providers and their patients before and after implementation of a telepsychiatry application to explain why the application was initially well-received but eventually abandoned(122). Another advantage of the ethnographic method is that it also allows researchers to ask open ended questions when studying clinical work rather than developing *a priori* research hypothesis to test(122). Ethnographic data gathering methods also allows for a variety of data to be captured. In the context of clinical work, this advantage can be crucial in capturing information not otherwise made available. For instance, early studies on clinician information needs focused on using self-reported data{Covell:1985co}; however, later studies which employed ethnographic observation identified information that physicians needed but did not self-report(125).

Despite the utility of ethnographic methods in studying clinical work, there are also a number of drawbacks. For instance, many ethnographic observation studies of clinical work are limited in their sample size and, therefore, have limited generalizability(126). In addition to limitations in the number of samples a researcher can collect, ethnographic studies often require extensive manual data analysis(127), making the process time-consuming. Another limitation of the method is that data analysis is often subject to the biases of the study team. Sometimes study teams may not be sufficiently distant from the team being studied, while other times researchers may not have enough understanding of the domain to draw conclusions appropriately(122).

A second group of widely used qualitative methods to study clinical work are interviews and focus groups. Interviews and focus groups have been used for a variety of purposes, including EHR design and usability(32,128), clinical workflows(80), and explaining many complex provider-to-provider and provider-to-patient relationships(129). Similar to ethnographic methods, interviews



and focus groups allow researchers to explore rich, and complex relationships. While interviews and focus groups questions are often scripted and prepared ahead of time, many are conducted in a semi-structure format allowing for the exploration of open ended questions as the research is being conducted. From a practical perspective, interviews and focus groups can be considered less intrusive to work processes as compared to other qualitative methods, such as ethnographic observations, which is a crucial advantage in studying clinical work.

Yet despite some of the advantages of using interviews or focus groups to study clinical work, there are some important limitations to be considered. One key limitation is that there are several threats to validity and generalizability. Interviews and focus groups are often limited by relatively small samples sizes and/or in the scope of settings studied. Additionally, responses to questions and discussions posed during interviews and focus groups are reliant on the research participants to accurately report and recall what they are describing. Furthermore, participants may inadvertently over or underreport the frequency certain healthcare process occur. Therefore, findings based on interviews and focus groups may have recall and anchoring biases. Similar to ethnographic methods, data analysis methods of interview and focus group data are generally manual and time consuming and difficult to scale to large numbers.

### **2.5.2 Quantitative Methods**

In addition to qualitative studies of workflow and communication, some quantitative methods have been used to study clinical work. Some have studied clinical workflow by using pervasive and ubiquitous devices, such as RFIDs(127) and Bluetooth location tracking(130). Others have used audit-logs or other logs of clinical systems in order to build different descriptive models to describe clinical workflows(131). In both approaches quantitative methods of workflow analysis,

data can be captured at a very large scale and often without extensive manpower or financial costs. For instance, RFID tags can be placed onto many personnel and devices at once(127), and many clinical systems inherently generate audit logs for administrative and legal purposes(131). Related to the ability to capture data at a greater scale, many quantitative methods can capture the perspective of multiple perspectives, which is a limitation of many qualitative methods. For instance, in ethnographic studies, observations are generally limited to a single individual or single location within the hospital; however, audit logs, for instance, collect every instance of a group of clinicians performing a select task(132) or performance of the entire hospital on a certain workflow metric(133); Yan:2016vb; Merrill:2015tc}.

Despite these demonstrations of using different quantitative methods to assess clinical workflow, these methods have some weaknesses as well. Audit logs of clinical systems are usually collected for administrative purposes and therefore do not always contain sufficient granularity for research use. Furthermore, these logs are often noisy and subject to data quality issues, which require extensive preprocessing, prior to any quantitative analysis. Data quality is also of concern in using RFIDs and Bluetooth tracking devices, as systems could become desynchronized(130), lose connection, and suffer from other hardware issues(127). Similarly, data from tracking devices must be continually checked to ensure that the data collected contains the right amount of granularity. Because some activities during clinical workflows and processes can occur very quickly, such as within seconds, timing mechanisms must be sensitive to these short durations(134).

### **2.5.3 Mixed-Methods**

A frequently mixed-methods approach to studying clinical work is time-and-motion analysis. Time-and-motion studies have been used frequently in healthcare to study clinical work(23,135-137). The popularity of time-and-motion studies is reflected in the perception of its accuracy in quantifying clinical work(138). Time-and-motion studies differ from ethnographic observations in that time-and-motion studies focus on studying the temporal durations of different tasks observed rather than focusing on identifying and explaining tasks and the relationships between tasks as in ethnographic studies. Ideally, the different tasks that are observed and recorded during time-and-motion analysis should be derived based on standardized and validated guidelines of work(139). A key advantage of the time-and-motion method is the ability for researchers to capture qualitative data about the clinical workflow as well in addition to the quantitative data. Because of this, time-and-motion analysis can also be used for workflow discovery and modeling, in addition to determining the frequency and duration of tasks(140). Some limitations of time-and-motion studies are the ability of the research team to collect data accurately and consistently, assessing inter-rater reliability among multiple observers, and possible disruption to clinical work. In time-and-motion studies, trained observers collect data, and therefore the data may be subject to certain data quality and accuracy issues. Observers have limited attention span, and they may miss some of the actions that are performed by the research participants. A further challenge observers face is the ability to accurately recognize and capture the tasks as they are being performed, especially when tasks are defined with high granularity or when research participants frequently switch tasks. A second limitation of time-and-motion studies is the difficulty in assessing inter-rater reliability(141). While traditional

qualitative studies often report inter-rater reliability scores, this practice has been substandard among time-and-motion studies. Part of this is due to the difficulty in defining agreement to calculate inter-rater reliability scores, but also because time-and-motion data contains multiple aspects, such as duration of tasks, sequence of tasks, frequency of tasks, and more (141,142). A last notable challenge to time-and-motion studies is the potential for disrupting the natural course of clinical work with too many observers. One way to overcome the challenge of multiple perspectives in clinical work is to increase the number of observers in a given study. However, increasing the number of observers also increases the chance of the Hawthorne effect and thereby biasing the data collected(143). Other studies using time-and-motion methodology, however, concluded that the Hawthorne effect likely had minimal impact on the data given sufficient researcher training(144).

#### **2.5.4 Application of Combining Research Methods**

Given that each analytic method has its own strengths and weaknesses in studying clinical workflow, the work presented in this dissertation relies on a combination of different methods to study clinical work, information needs, and information sharing. The goal of using a combination of methods in a single study is to use the results of each method to triangulate findings. Furthermore, while there have been previous studies that used a combination of methods to analyze and study clinical workflow, these studies are relatively rare compared to studies that utilize only a single analytic method. However, given that this dissertation focused on studying clinical work among teams, it seemed only appropriate to study clinical work and information sharing with many different approaches.

## Chapter 3: Aim I - Impact of EHRs on Clinical Teamwork

### 3.1 Background

Handoff is the transfer of information and responsibilities for a patient from one provider to another(70). It is an essential part of contemporary healthcare operations and occurs at different times of healthcare process, such as during shift change, patient transfer, and other instances of transitions of care(33,145). Handoffs take many different forms, most frequently as verbal conversations accompanied by written documentation(90,98). Despite the importance of communication during handoff, the Joint Commission found that 80% of adverse events could be attributed to miscommunication during the handoff process(39). To reduce these risks, many interventions have been implemented to improve various aspects of handoffs, from standardizing verbal communication that typically accompanies transitions of care(47,48,90) to aiding documentation during handoff(28,32,146), and even the physical designs of locations where handoffs occur(17). Recent studies investigating multi-component bundled interventions for improving handoff have largely been shown to be successful in reducing errors and improving other important outcomes(16,17). One increasingly popular solution for improving handoff is through introduction of electronic handoff tools. These tools provide clinicians with an ability to document information pertaining to handoff and are often integrated with EHR systems(147).

A recent review showed that while handoff tools have been studied in respect to a wide range of measures, few previous studies specifically focused on understanding the effect of these tools on clinical teamwork(147). This knowledge gap is important for a number of reasons. First,

while electronic handoff tools are often designed for a particular target group, such as residents or nurses, multiple studies have shown increased adoption of these tools by clinicians in various roles, outside of their intended users (28,29,32). Second, while handoffs generally occur between providers with the same clinical role, clinical teams are affected by the effectiveness of individual handoff communication. Thus, it is critical to understand the impact of electronic handoff tools not only on individuals performing the handoff, but also on patient care teams. Considering these literature gaps, in this aim, I explored the impact of the Handoff Tool, a locally adopted electronic handoff documentation tool, on teams and teamwork. Specifically, I examined its impact on patterns of communication during verbal handoff, shared mental models within patient care teams, and clinical workflows and information sharing.

### 3.2 Aim I Research Questions

1. What is the impact of Handoff Tool on different characteristics of handoff conversation, such as interactivity and question asking?
2. What is the impact of Handoff Tool on shared mental models within patient care teams?
3. How does Handoff Tool impact clinical workflow and information sharing?

### 3.3 Study 1A: Handoff Tool Impact on Conversation Elements

#### 3.3.1 Background

In 2006, the Joint Commission (JC) made recommendations to improve handoff communication, such as increasing conversation interactivity or turn-taking during handoff conversation and ensuring that clinicians have opportunities to ask questions during

handoffs(33). *Cohen et al.* and *Hilligoss et al.* have argued that conversation interactivity is crucial to developing shared mental models during clinical handoffs(35). Empirically, *Fusaroli et al.* showed that more interactive conversations led to improved team performance by promoting team alignment (148). Similarly, question asking allows clinicians to ensure a chance to resolve unmet information needs(73) and prevent information gaps from forming(72).

However, despite evidence showing the importance of interactivity and opportunities to ask questions, there has been a lack of understanding of whether an electronic handoff tool, such as Handoff Tool, can increase interactivity and question asking during verbal handoffs.

While conversation interactivity is a critical characteristic of the verbal handoffs between two individual clinicians, handoffs have also been shown to play a major role in developing and maintaining shared mental models of the patient for the entire team(33,149). Even in the context of interdisciplinary teams, researchers have argued that handoffs help members establish a shared understanding of patient care needs and to coordinate responsibilities(150,151). However, there are several threats to interdisciplinary teams' ability to consistently form a clear understanding of the patient. Because clinical handoffs are typically conducted as individual conversations between clinicians in the same role, they can contribute to divergence, rather than alignment among members of patient care teams, for example, in cases when handoffs by different clinicians on a team include inconsistent or contradictory information. With the introduction of electronic handoffs tools that are accessible by all clinicians on the team, it is plausible that such tools can increased the degree of overlap in SMM among interdisciplinary teams.

Therefore, the main objective of this study was to evaluate the impact of electronic handoff tools on individual clinicians and teams during handoffs. The two focus areas for evaluation are handoff conversation interactivity (individual) and SMM during handoff (teams). Handoff interactivity is measured by both the conversation interactivity and the frequency of questions during handoff. SMM is assessed by the amount of content overlap and the frequency of discrepancies between the handoffs of each clinician on the team.

### **3.3.2 Methods**

#### *3.3.2.1 Setting*

This study took place in the pediatric intensive care unit (PICU) of a metropolitan, academic-medical center with a patient load of 1,800 patients per year. Patients had a range of acute and/or chronic issues with varying levels of severity. The PICU was divided into two sections, each with its own team of one attending physician, one clinical fellow, approximately five residents or nurse practitioners, and bedside nurses. Each pair of attending physician and fellow cared for all patients in their respective section of the PICU, while the residents self-assigned patients to distribute patient care equally. Nurse practitioners serve in an analogous role to residents, with the exception of clinical rotations throughout the hospital. Bedside nurses were assigned to patients in a 1 to 1 or 1 to 2 ratio.

#### *3.3.2.2 Handoff Workflow*

In this study, three clinical roles were studied: 1) fellows, 2) residents, and 3) nurses. All three roles perform verbal handoffs during morning and evening shift change. Fellows had the least regular handoff workflow with varying times and locations for when and where verbal handoffs were performed. For residents, morning handoffs generally occurred at around 7am; however,



evening handoffs had greater time variability. Most resident handoffs were conducted in one of two resident work stations, which contained computers. While the computers were made available, use of the EHR or computer in general were not required. Nursing handoffs were the most regular, occurring at around 7am and 7pm each day and usually by the bedside. Some nursing handoffs in this study included nurse trainees, who conducted verbal handoffs under the supervision of their mentors; however, these were rare. Lastly, with the exception of the nurse trainees, all clinicians performed verbal handoffs independent of review.

Prior to the implementation of Handoff Tool, clinical fellows wrote hand-written, free-form notes to facilitate verbal handoffs. Resident physicians finishing their shifts filled out paper forms based on a body systems perspective, which contained information important for patient handoff. This form was passed to the incoming resident during verbal handoffs. Nurses documented in handwritten, free-form format as well to prepare for handoff. Similar to other clinical roles, the handwritten document could be passed to the following clinician if desired. Prior to the implementation of the Handoff Tool, there were no dedicated electronic tools to support clinicians engaged in verbal handoffs.

Following implementation of Handoff Tool, all physicians had both editing and viewing access. While neither fellows nor residents were required to use the tool, the tool was primarily assumed to be used by residents. Residents could still revert to using the structure paper forms before the Handoff Tool was implemented; however, updating the information in the Handoff Tool was considered a resident responsibility. Nurses could view information found in the Handoff Tool; however, they were not permitted to edit information in the tool.

### *3.3.2.3 The Handoff Tool Description*

The Handoff Tool was initially developed by *Vawdrey et al.* to aid adult internal medicine residents document information pertinent to verbal handoffs(32). Following initial deployment to the internal medicine wards, the Handoff Tool was deployed hospital-wide with no changes for individual units. The tool was accessible through the primary EHR interface and was made up of nine free-text boxes, where residents could enter information. Each of the free text-boxes was labeled but adhering to entering information based on the label was not enforced. At the time of the study, the labels found in the tool were 1) Patient Summary, 2) Active Issues, 3) Contact Info (for the patient), 4) Primary To Do List, 5) Notes/Comments, 6) Coverage To Do List, 7) Hospital Course, 8) Discharge Planning, and 9) Consult Handoff. All users of the EHR, regardless of clinical role, could create printouts from the Handoff Tool that included a cover page, listing all patients under the user's care, as well details of each individual patient. Detail patient information included information from the free-text boxes as well as some structured information, such as medication orders and laboratory results. Another function of the Handoff Tool allowed users to view iterative versions of the document created by the Handoff Tool, similar version control or track-changes functions found in common word processors.

### *3.3.2.4 Data Collection*

Verbal handoffs in the PICU were recording during two study periods: pre-implementation period (November 1 to December 21, 2011) and post-implementation (March 1 to May 31, 2012). The pre-implementation period took place just prior to the implementation of the Handoff Tool, while the post-implementation period took place two months after the implementation of the Handoff Tool. Handoff conversations were recorded during both the

morning and evening shift changes. Written informed consent for each clinical participating in the handoff conversation was obtained prior to the beginning of the verbal handoff for pre-specified patients. The recorded handoffs were professionally transcribed, and the transcripts were verified for accuracy. Collection of the audio recordings and verification of the transcripts for accuracy were done by a team of investigators.

This study was approved by the Institutional Review Board (IRB) at Columbia University Medical Center.

#### *3.3.2.5 Interactivity and Question Frequency Analysis*

To calculate a verbal handoff's interactivity score, transcripts were segmented into the smallest unit that contained a medical fact. For instance the sentence "So CV, I told you his max was 102.7, one dose of Tylenol today" would be broken down into "So CV, I told you his max was 102.7", "one dose of Tylenol", and "today". After each handoff was segmented, the number of turn-taking, that is switches in the person speaking in the conversation, was counted. The interactivity score for the handoff was then calculated for the handoff based on the following formula.

$$\text{Interactivity} = \frac{\# \text{ of turn} - \text{taking}}{\text{Total \# of conversation segments} - 1}$$

For the interactivity score, the denominator is defined as one minus the total number of conversation segments because there will always be one more conversation segment than the maximum number of turns possible in a conversation. A completely interactive conversation, where the interactivity score equals 1, both speakers must take turns speaking after each

segment, or coherent medical fact. A conversation that lacks any interactivity features a verbal exchange where only one speaker speaks the entire time, which results in a score of 0.

The benefit of this approach, compared to counting the number of segments each participant speaks, is that it models turn-taking as a measure of conversation engagement. The benefit of incorporating turn-taking to measure engagement is modeled by the following example. An analysis that focuses on a ratio of speech by two conversation participants would rate highly a conversation where the two participants spoke without taking turns, that is the first speaker dominates the conversation and is then followed by the second speaker dominating. From a turn-taking perspective, this conversation has low interactivity because there is a lack of back and forth exchange, which would suggest engagement question asking.

To calculate the frequency of question asking, each question was identified in the transcripts and coded as being a: 1) follow-up question, 2) information seeking question, or 3) information and timely verifying question. Follow-up questions request for further information about a topic just presented, while information seeking questions request for information on a topic not previously covered. Information verifying questions read back or repeat the information in any variation information that was just recent presented. The number of questions and question sub-types for each handoff were divided by the number of segments for that handoff in order to account for varying handoff durations.

#### *3.4.2.4 Content Overlap and Discrepancy Analysis*

After every handoff in the handoff group was segmented, segments that contained the same information were identified and labeled as overlapping. Notably, overlap was determined based on semantic rather than syntactic similarity. If two segments were syntactically different,

but semantically similar, they would still be marked as an overlap. As an example, if the resident had explained that “([the patient] has been on nitric for a while,) but that’s been weaned to off”, whereas the nurse said “[the patient] is off (nitric)”, these two segments would be considered overlapping, because they both show that the patient was on nitric before, but is no longer on it now.

In addition to content overlaps, we also identified content discrepancies. Whereas overlaps convey the same or very similar concepts, discrepancies highlight contradictory or misaligned information. In a variation of the previous example, if the resident had said “([the patient] has been on nitric for a while,) but that’s been weaned to off”, but the nurse had said “[the patient] is has (nitric)”, then these two segments would have been considered a discrepancy, because one clinician had reported that the patient was not receiving nitric currently, but another clinician had reported that the patient was. Not all discrepancies contained contradictory information. Sometimes, clinicians simply presented misaligned information, such as a resident reporting “[the patient] needed just one additional (Versed bolus overnight)” while the nurse reported “there were a couple of times (last night that I ended up asking for extra Versed boluses”. In this example, both clinicians showed a shared understanding that the patient received additional Versed overnight; however, they were misaligned in their shared understanding of how much additional medication had been administered. An important note is that this analysis did not include assessing which of the discrepant statements was more accurate, but rather on agreement or lack thereof between different handoffs corresponding to the same patient during a given transition of care.

After all discrepancies had been identified, a PICU attending physician reviewed all discrepancies to ensure that factual differences in handoffs were clinically important. During this review process, the attending physician was blinded to the implementation study period during which discrepancies occurred. All discrepancies that were labeled as clinically insignificant were removed and excluded from subsequent analysis. An example of a discrepancy deemed clinically insignificant would be when the resident stated that the patient had a systolic blood pressure of 65-80 mmHg but the nurse stated that the patient had a systolic blood pressure between 70-85 mmHg.

Based on the definitions of content information and discrepancies, the lack of content overlap does not imply a discrepancy occurred. A lack of overlap can suggest a divergence in priorities of different aspects of the patient care, such as when nurses discuss the patient's pain level during handoffs, but residents discuss sedative medication. While the bigger picture may be similar, the details are not overlapping. Furthermore, a lack of overlap does not definitively suggest that clinicians do not have a shared understanding. The method described here focuses primarily on identifying explicit content overlap, and does not attempt to estimate the shared understanding of the patient that is not discussed during verbal handoffs.

To quantify content overlap, each handoff group was scored based on the pyramid method, originally developed by *Nenkova et al.* (152). For each handoff group, previously identified overlapping segments were placed into different levels of the pyramid. Segments that were unique to a single handoff in a group were placed on the bottom level of the pyramid. The remaining levels were determined based on the number of clinicians in the handoff group. If there were only two clinicians captured in the handoff group, then the pyramid simply had two

levels, one level for all segments that did not overlap and another level for all segments that overlapped. If there were three clinicians captured in the handoff group, then the pyramid had three levels, one level for all segments that did not overlap, a middle level for segments that only overlapped between two clinicians, and a top level for segments that are overlapped between all three clinicians. Each level of the pyramid was assigned a level value based on the number of clinicians in the handoff group. The bottom level has a level value of 0, while the top level has a level value of 1. In handoff groups with three clinicians (or more), the middle level(s) is valued at the number of overlapping clinicians divided by the total number of clinicians in the handoff group. In this study, the maximum number of clinicians in a handoff group was always 3, so the value of the middle level was  $2/3$ . If there had been a handoff group with 4 clinicians, the levels would be valued at 0 (no overlap), 0.50 (2 clinicians overlapping), 0.75 (3 clinicians overlapping), and 1 (4 clinicians overlapping). All levels of the pyramid were then scored. The score for each level of the pyramid was calculated as the product of the number of segments multiplied by the pyramid level value. More examples and applications of the method can be found in *Mamykina et al.*(153).

To analyze discrepancies further, all discrepancies were coded based on their content using a classification system of handoff communication adapted from *Apker et al.*(154). Because the *Apker et al.* classification was originally developed for handoffs between the emergency department (ED) to inpatient setting, minor modifications were made to account for differences in handoff communication between ED physicians and critical care unit clinicians. Specifically, under the original category “Assessment/Treatment” we included sub-categories referring to treatment administration (if a particular treatment or medication was

administered), and dosage (the actual dosage of administered treatment) because of the high frequency of discrepancies in these categories. In addition, we changed the definition of the category “Outcome” to include statements regarding outcomes (or results) of past treatments or procedures (e.g. “the patient tolerated weaning well”) from its original meaning of outcome of handoff (e.g., accept or not accept to the unit) and “Assessment/Transfer of Responsibility” to include any specific instructions in regards to the anticipated care for the upcoming shift (instead of its original meaning of “Statements about what was being asked of the hospitalist (e.g., patient admission, clinical consult, other reason)”). All the other categories and sub-categories remained unchanged.

To assess inter-rater reliability, 10% of the dataset (5 handoff groups) were coded independently by a clinician not involved in the previous phases of the analysis. After a shared coding exercise the clinician was asked to complete coding independently. Results and discrepancies between the clinician and the primary author were discussed and resolved. After the exercise, the clinician coded 5 handoff cycles, by breaking handoff transcripts down to segments, and identifying overlapping and discrepant segments independently. The segments that matched between the clinician and primary author, as well as the number of segments marked as overlapping and discrepant were counted, with disagreements noted.

#### *3.3.2.5 Analysis of Pre-/Post- Differences*

In order to determine whether there were changes to either interactivity or the rate of question asking after the implementation of the Handoff Tool, a two-sample, unequal variance t-test was used to test for changes in the mean values of the two main outcomes. If either t-test showed a significant change, subgroup analysis to determined whether a particular clinical role



had different levels of interactivity or rate of question asking was performed using a two-sample, unequal variance t-test for each role with a Bonferroni correction. To determine that changes were not the result of changes to handoff duration, a two sample, unequal variance t-test was used to determine if a change in the number of segments per handoff occurred when compared pre-Handoff Tool intervention to post-Handoff Tool intervention. All statistical tests were performed with R (version 3.3.3).

To evaluate content overlap scores and the rate of discrepancies before and after the implementation of the Handoff Tool, a Wilcoxon-Rank sum test was used. To example the potential impact of incomplete handoff groups (handoff groups with only 2 clinicians), a Kruskal-Wallis test was used to determine whether different combinations (i.e. resident-fellow handoff groups versus resident-nurse handoff groups) of providers had significantly different content overlap score.

#### *3.3.2.6 Member Checking*

To corroborate and elicit user comments on the results of the study, initial findings were presented to an audience of residents, fellows, and attending physicians at a regularly scheduled PICU staff meeting. After a presentation of the results, the clinicians provided feedback and contextualization of the presented results. Notes of the discussion were taken.

### **3.3.3 Results**

One-hundred and forty-five verbal handoffs were included in the study. Forty-five percent of these handoffs (n = 65) took place prior to the implementation of the Handoff Tool, while the remaining (n = 80) took place after the Handoff Tool was implemented. Twenty-three percent of the handoffs belonged to clinical fellows (n = 34), while thirty-four percent belonged to

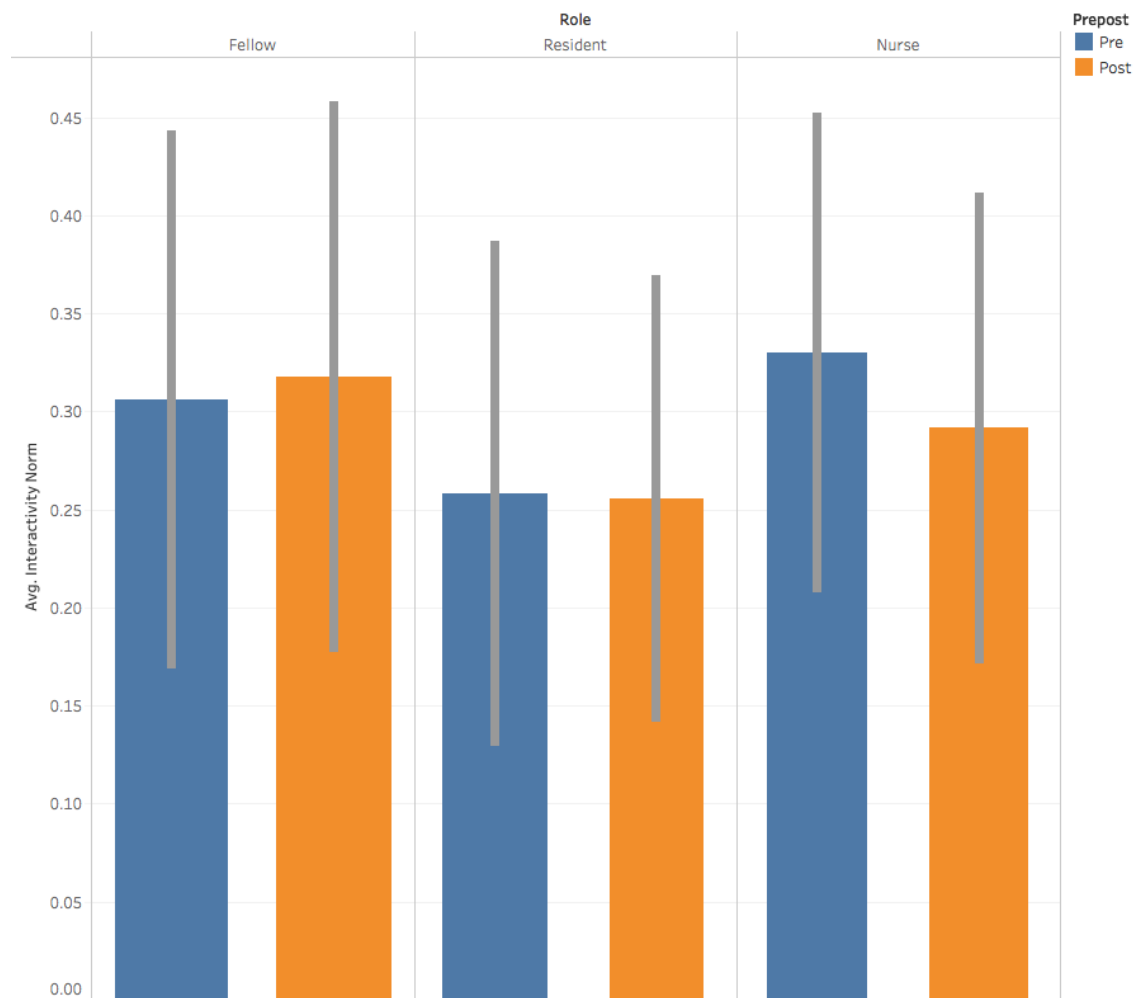
residents (n = 50), and the remaining forty-two percent (n = 61) belonged to nurses. A full breakdown of the number of handoffs for each clinical role per time period can be found in Table 3.1. Across all handoffs, the average length was 233 handoff segments (standard deviation, s.d., = 187). There was no difference in handoff length as measured by the number of segments before-/after- the implementation of the Handoff Tool ( $t = 0.11$ ,  $p = 0.92$ ). Prior to the Handoff Tool being implemented, the average length was 232 segments (s.d. = 176), while the average length after the Handoff Tool was implemented was 235 segments (s.d. = 197).

**Table 3.1** Means and standard deviations of handoff lengths pre-/post-Handoff Tool by role

	Pre		Post	
	Mean	Standard Deviation	Mean	Standard Deviation
<b>Fellows</b>	83	146	65	33
<b>Residents</b>	181	76	178	81
<b>Nurses</b>	330	187	404	203

### 3.3.3.1 Results on Interactivity

Across clinical roles, there was no difference in handoff interactivity between implementation study periods ( $t = 0.64$ ,  $p = 0.52$ ). The average handoff interactivity before the Handoff Tool was implemented was 0.30 (s.d. = 0.13). The average handoff interactivity after the Handoff Tool was implemented was 0.29 (s.d. = 0.12). Figure 3.1 visualizes the subgroup analysis, which showed that there were no significant changes in to handoff interactivity between study periods (fellows:  $t = 0.233$ ,  $p = 0.82$ ; residents:  $t = 0.08$ ,  $p = 0.93$ ; nurses:  $t = 1.24$ ,  $p = 0.22$ ). There appears to be no consistency in the small changes to handoff interactivity. Residents and nurses saw a slight decrease in interactivity, whereas fellows saw a slight increase in interactivity.



**Figure 3.1** Means and standard deviations of handoff interactivity pre-/post-Handoff Tool by role. The bars show the average interactivity score, normalized for each role and study period. The grey bars show the standard deviation value

### 3.3.3.2 Question Asking

Across clinical roles, there was a statistically significant decrease in the rate of questions after the Handoff Tool was implemented ( $t = 2.33$ ,  $p = 0.02$ ). The mean rate questions were asked before the Handoff Tool was implemented was 0.036 (s.d. = 0.024), and the mean question asking rate after the Handoff Tool implementation was 0.028 (s.d. = 0.017). Analyzing the rate of question asking for each role, no particular clinical role had a significant decrease in question

asking (Table 3.2). Within role analysis showed that fellows and nurses had dramatic reductions in question asking, but residents had a barely detectable reduction.

**Table 3.2** Mean and standard deviation of frequency of questions asked pre-/post-Handoff Tool by role

	Pre		Post		P-Value
	Mean	Standard Deviation	Mean	Standard Deviation	
<b>Fellows</b>	0.038	0.024	0.024	0.020	0.07
<b>Residents</b>	0.029	0.020	0.028	0.017	0.85
<b>Nurses</b>	0.041	0.026	0.030	0.016	0.07

Because questions can be asked for a variety of reasons, an analysis on the frequency of question subtypes was also conducted. On average, information follow-up questions were the most frequently occurring subtype for all three clinical roles. Questions asked to verify previously discussed information occurred the least frequently, and again this finding was true for all three roles. Regarding changes in question subtype frequency, residents and nurses had statistically fewer information seeking questions in their handoffs after implementation of the Handoff Tool (Table 3.3), even when adjusting for multiple hypothesis correction using Bonferroni Correction.

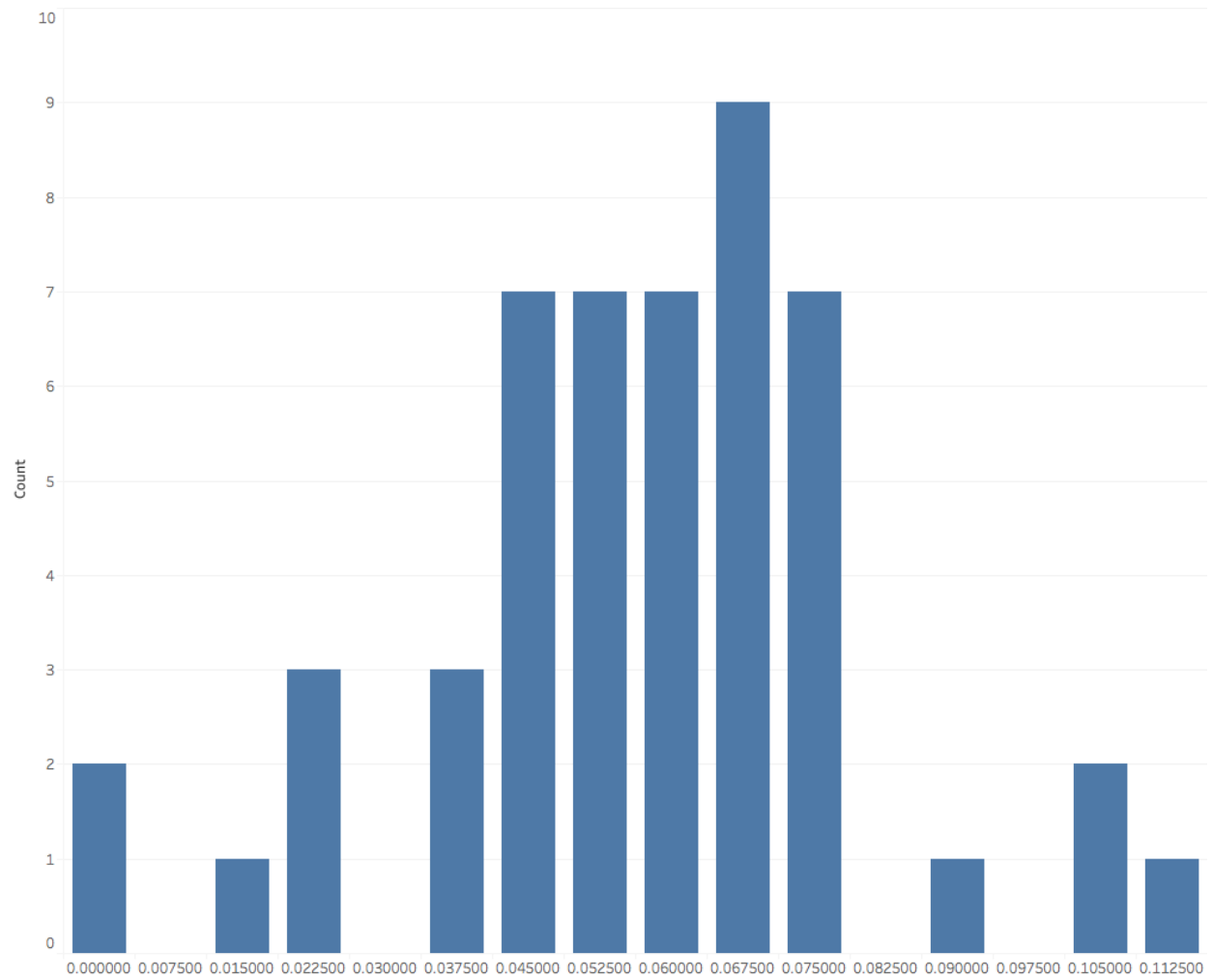
**Table 3.3** Mean and standard deviation of question subtype frequencies pre-/post-Handoff Tool by role

	Pre		Post		P-Value
	Mean	Standard Deviation	Mean	Standard Deviation	
<b>Fellows</b>	0.033	0.032	0.021	0.027	0.29

<b>Information Follow-up</b>	<b>Residents</b>	0.027	0.019	0.024	0.017	0.52
	<b>Nurses</b>	0.037	0.035	0.027	0.013	0.14
<b>Information Seeking</b>	<b>Fellows</b>	0.023	0.033	0.013	0.016	0.34
	<b>Residents</b>	0.016	0.013	0.007	0.008	<b>0.008</b>
	<b>Nurses</b>	0.016	0.011	0.008	0.008	<b>0.005</b>
<b>Information Verifying</b>	<b>Fellows</b>	0.004	0.007	0.001	0.003	0.25
	<b>Residents</b>	0.007	0.007	0.005	0.005	0.54
	<b>Nurses</b>	0.006	0.016	0.005	0.007	0.55

\* Bolded p-values signify significant different between pre-/post-Handoff Tool mean frequency after adjusting for Bonferroni Correction.

Content overlap scores ranged from 0.002 to 0.12, with the median content overlap score across all handoffs 0.06. As demonstrated in Figure 3.2, there are two small tails, and a large middle group of handoff groups clustered around the median overlap score. On the lower tail, 6 handoff groups fell between 0 (minimum theoretical score) and 0.028. The middle overlap score category, where handoff groups scored between 0.042 and 0.082, contained 40 handoffs, which was by far the largest cluster of handoff groups. The high content overlap score category included handoff groups that scored 0.094 and above, and there were 4 handoff groups that fell within this category. When taking consideration of the Handoff Tool implementation, the median content overlap score before and after implementation was 0.06 and 0.06 respectively (Table 3.4). There was no statistical difference in content overlap scores between the two study periods ( $W = 288$ ,  $p = 0.75$ ).



**Figure 3.2** Histogram plot of overlap scores. Bins of overlap scores run across the X-axis, while the Y-axis represents the frequency of each bin.

**Table 3.4** Descriptive statistics of overlap scores and discrepancies pre-/post-Handoff Tool

	Overlap Score		Discrepancies	
	Pre	Post	Pre	Post
<b>(Min, Max)</b>	(0.006, 0.08)	(0.002, 0.12)	(0, 2)	(0,5)
<b>Mean</b>	0.06	0.06	0.76	1.17
<b>Median</b>	0.06	0.06	1	1
<b>Standard Deviation (SD)</b>	0.02	0.03	0.72	1.6

When analyzing the overlap score between handoff groups with different compositions, there were no statistical differences ( $\chi^2 = 4.32$ ,  $df = 3$ ,  $p = 0.23$ ). Therefore, no post-hoc tests were conducted. As Table 3.5 shows handoff groups that included only fellows and residents did not have a higher than handoff groups that included nurses. This analysis showed that the results were not sensitive to prior clinical training.

**Table 3.5** Handoff groups type, frequency, and median overlaps

Team Type	Count of Team Type	Median Overlap Scores
Fellow, Resident, Nurse	23	0.059
Resident, Nurse	19	0.069
Fellow, Nurse	5	0.057
Fellow, Resident	3	0.068

Along with content overlap, discrepancies were also analyzed. Among the 50 handoff groups, 50 discrepancies were identified. The median rates of discrepancies before and after the Handoff Tool was implemented were 1 and 1, respectively. Discrepancies were not equally distributed among handoff groups. Prior to the Handoff Tool being implemented, the range of

discrepancies found among groups was between 0 and 2 discrepancies; however, after the Handoff Tool was implemented, the range of identified discrepancies increased to be between 0 and 5 discrepancies (Table 3.6).

**Table 3.6** *Count and proportion of discrepancies per handoff group*

<b>Number of discrepancies per Handoff Group</b>	Proportion of teams with a given number of discrepancies	
	<b>Pre: proportion (n); total n=21</b>	<b>Post: proportion (n); total n=29</b>
0	43% (n=9)	34% (n=10)
1	38% (n=8)	38% (n=11)
2	19% (n=4)	14% (n=4)
3	0	7% (n=2)
4	0	3% (n=1)
5	0	3% (n=1)

Table 3.7 contains the categories of discrepancies and the rate at which they occurred. Almost all identified discrepancies were related to patient presentation, especially medications and procedures, as well as symptoms. The discrepancies of this nature increased after the implementation of the Handoff Tool, but not equally among all categories. While discrepancies related to the frequency or dosage of medications and procedures increased, as did discrepancies related to symptoms, discrepancies related to whether medications and procedures had been administered dramatically fell.



**Table 3.7** Categories and frequencies of information discrepancies during handoffs

Category of discrepancy	Subcategory of discrepancy	Rate of discrepancy (total: pre/post)	Example
<i>Patient Presentation</i>		(0.84: 0.71/0.93)	
	Patient Identifiers	(0.02: 0.02/0)	Resident: [patient name] is 5 months old Nurse: He is, I believe, nine months
	Symptom	(0.38: 0.29/0.44)	Resident: He's still tachypneic Nurse: He's not tachypneic.
	History	(0: 0/0)	NA
	Procedure (administration)	(0.26: 0.43/0.14)	Resident: But we didn't put any thrombin on it last night Nurse: I put thrombin on it and got a nice dry
	Procedure (dosage)	(0.20: 0/0.34)	Fellow: So I went up on the Lasix drip 0.08 Resident: So we wean on the Lasix drip slowly, 0.3, 0.2
<i>Assessment</i>		(0.08: 0/0.14)	
	Treatment	(0: 0/0)	NA
	Clinical Impression	(0.04: 0/0.07)	Resident: The x-ray just got like whited out again Nurse: But his right lung is definitely better
	Prognosis	(0.04: 0/0.07)	Resident: She can actually probably go to the floor today Nurse: So I don't think the floor today
	Outcome	(0: 0/0)	NA
	Transfer of responsibility	(0: 0/0)	NA
<i>Other</i>		(0.06: 0/0.10)	

\* Italicized text represents a major category of content discrepancies.

There was high inter-rater reliability for the qualitative coding. The raters agreed 74.8% of the time when segmenting handoff transcripts. The primary author disagreed with the clinical rater's segments 14.3% of the time, while the clinical rater disagreed with the primary author's segments 10.9% of the time. The kappa for identifying overlapping content was 0.93, while the kappa for identifying discrepancies was 0.69.

#### *3.3.3.3 Member Checking*

To conduct member checks, we presented the initial results to residents and fellows of the PICU participating in this study. Overall, the participants agreed with the findings and explained how they had incorporated Handoff Tool into their workflows and, specifically, a change in their handoff process. They reported more frequent checking of patient status prior to receiving the verbal handoff to start their shifts. They attributed this change in their workflow to the increased visibility and improved access to the condensed summary of pertinent patient information available within the Handoff Tool. Some clinicians reported the perception of being more informed about the patient prior to handoff because of the Handoff Tool. These results suggest that the Handoff Tool was frequently integrated into clinicians' handoff workflows even though using the tool was not required.

#### **3.3.4 Discussion**

While a previous literature review identified a number of previous studies that evaluated electronic handoff tools on multiple variables (147), only few of these studies have focused on the impact of electronic handoff tools on measures of clinical teamwork. Consequently, the focus of this study was to understand the impact of a locally implemented electronic handoff tool, the Handoff Tool, on two characteristics of clinical teamwork, communication and shared

mental models. Each characteristic of teamwork had two outcome measures. The two measures of communication were conversation interactivity and rate of question asking; these measures were tied to the recommendations by the Joint Commission for improving clinical handoffs. The two measures of shared mental models included content overlap and information discrepancies, which were previously proposed and evaluated by *Mamykina et al.* {Mamykina, 2016}.

Relative to conversation interactivity, previous research found interactivity to be crucial to verbal handoffs(155); however, further research has found interactivity in handoffs to be low(156). The results of this study showed that in contrast to previous work, handoffs can be quite interactive. Regardless of the Handoff Tool implementation, the average conversation interactivity was roughly 0.30. This translates to a conversation turn taken after every roughly three statements. Practically demonstrated, this means that on average, after a resident says “So CV, I told you his max was 102.7, one dose of Tylenol today”, the other resident would then likely follow up with a question or present another fact to turn the handoff into a discussion. An important aspect of this study was to also evaluate the impact of Handoff Tool on conversation interactivity, and this study did not find a relationship between interactivity and implementation of the tool. This suggests that the Handoff Tool and the associated workflow changes identified during member checking may not be enough to change or improve conversation interactivity.

Relative to question asking in handoff, previous research has generally studied this activity using two methods: 1) percentage of handoffs captured that included at least 1 question, and 2) percentage of handoff conversation that involved a question. *Babu et al.* and *Iedema et al.*

both used the first method and found high rates of handoffs that contained at least one question among neurosurgery residents(89) and emergency medicine residents(157). However, when *Apker et al.* used the second method, only a few questions were interspersed within the whole verbal handoff(154). The findings in this study are similar to findings from both analysis of question asking. Most handoffs included in this study had at least one question asked by the clinician receiving the handoff, and individual handoffs had low rates of questions asked. When analyzing the impact of Handoff Tool on the rate questions were posed during verbal handoffs, the results show an overall decrease after Handoff Tool was implemented. Fellows and nurses exhibited a strong trend towards having statistically fewer questions during handoffs, while residents remained consistent between the two study periods. When questions are categorized into subtypes, information seeking questions showed a very strong decrease among nurses and residents. This quantitative finding is reflected in the qualitative member checks, when clinicians reported the perception of being more prepared for the verbal handoff by having a tool to help them understand the patient's clinical condition quickly beforehand.

The content overlap scores in this study were comparable to results from a previous study of content overlap in critical care(153). The results from this study show that content overlap in handoffs is relatively low even for what appears to be otherwise high-functioning teams. In *Mamykina et al.*, high-functioning teams had an overlap score of 0.04 or higher, which would include the medium-scoring and high-scoring handoff groups in the current study(153). The combination of results from the current and previous study reinforces general idea that higher levels of SMM are correlated with improved performance; however, it also shows that high performing teams do not require a complete overlap of understanding in their handoffs. This

finding is supported by previous studies of SMMs that showed among highly specialized, interdisciplinary teams diversity of knowledge was critical to team performance(158). Furthermore, both the study by *Mamykina et al.* and the one presented here show that more further research is needed to more fully understand the significance of the content overlap score and its association with team performance and patient outcomes. For example, it is not possible to assertively claim what degree of overlap is necessary and appropriate to ensure successful functioning of a team. However, in these previous studies, content overlap score was positively correlated with other, better studied measures of team performance. At the moment, content overlap scores can be used to compare relative overlap between different teams, or to study the impact of different interventions.

While the changes in content overlap scores were negligible, rates of discrepancies increased after the implementation of the Handoff Tool. In addition to higher rates of discrepancies, the range of discrepancies also grew larger. In fact, four handoff groups in the post-Handoff Tool implementation phase had 3 or more discrepancies, which translates to 30% of the of all discrepancies identified in the study, despite representing only 8% of all handoff groups. While this study did not delve further into these four teams, further research should explore whether teamwork factors are related to the prevalence of discrepancies at handoff.

Another finding related to discrepancies was that Handoff Tool did not have a consistent effect. While in general, discrepancies rates increased following Handoff Tool implementation, not all categories of discrepancies were affected the same way. Discrepancies related to shared awareness of medications or procedures being performed decreased, while discrepancies related to shared understanding of the patient's symptoms and dosing of medication and

frequency of procedures increased. Many reasons could have explained these increases, and one of these reasons may be the design of the Handoff Tool. Implementation of the Handoff Tool may have led to an increased reliance of on handoff notes as an important source of patient information and a reduction in information seeking else in the EHR. Medication dosage and treatment frequency information are information not explicated included in the free-text boxes of the Handoff Tool, but they are information available elsewhere in the EHR.

Overall, this study showed that the Handoff Tool did not have a significant impact on the selected measures of teamwork. This finding further reiterates the importance of systemic approach to implementation of informatics interventions. Previous studies have already suggested that informatics solutions for improving handoff achieve their desired impact when accompanied by other interventions that include process redesign and personnel training. Indeed in *Starmer et al.*, implementation of an electronic handoff tool appeared to have little impact on reducing the rate of adverse events(17); yet was successful as part of a more complex bundled approach. In contrast to these previous efforts, the Handoff Tool in our study was implemented more organically, without training or clear instructions for how to integrate usage of the tool into clinicians' work and communication practices. These findings suggest that in order to effectively improve complex processes, such as clinical handoffs, bundled intervention approaches, that incorporate multiple components including education and process changes, are needed.

An another explanation for Handoff Tool's limited impact on teamwork measures is the short time frame between the implementation of the tool and the post-implementation data collection period. Previous studies have demonstrated that implementing new tools often

results in disruption of existing work practices(159-161). It is possible that introduction of the Handoff Tool had a temporary disruptive effect on verbal handoff communications, which included decrease in questions asked during verbal handoffs and increase in the number of discrepancies. Future research should consider allowing for a more extended time periods that would allow clinicians needed to form new practices that involve using the tool.

#### *3.3.4.1 Limitations*

This study had a few limitations. First, the verbal handoffs in the study were captured in a single pediatric intensive care unit, and therefore, may have limited generalizability of the study results to non-pediatric and non-intensive care units. Secondly, several of the handoffs shared a select number of clinicians, which may have skewed the results. Additionally, clinician properties, such as experience, patient load at time of handoff, and other factors, were not controlled for during data collection and analysis. This study may have been biased by the inherent experience residents and fellows gained as they trained throughout the year. The pre-Handoff Tool implementation occurred in the first half of their post-graduate year training, while the post-Handoff Tool study period occurred in the second half of their post-graduate year training. Therefore, the need for fewer questions during clinical handoffs could have occurred as a result of increased training and general medical education rather than due to Handoff Tool and its associated workflow changes. This limitation also extended to analysis of content overlap, where fewer topics were discussed because clinical team members had been working together for a longer period of time in the post-implementation phase of Handoff Tool. However, because nurses also experienced changes to their verbal handoff after

implementation, it would appear that Handoff Tool had at least some influence on the changes to the verbal handoff.

Three limitations specific to the evaluation the impact of Handoff Tool on SMMs were that some handoff groups were captured at various times of a single patient's hospital courses. Some handoff groups occurred earlier during earlier periods of a patient's care, while others occurred later, when the plan of care was well established. Factors, such as these, were not controlled for in analyzing pre-/post-implementation differences. A limitation of using content overlap, as defined in this study, to approximate SMMs, was that it did not account for knowledge shared among team members that was not discussed during handoff. For instance, team members may have shared understandings about a patient's disease or symptoms that are not discussed but still known. Related, information may not have been passed during verbal handoffs because the clinician giving the handoff may have prior awareness of the receiver's understanding of the patient. This too limited the ability of content overlap to estimate SMMs. Overall, the use of content overlap score to approximate SMMs was only a conservative estimate of a team's SMMs. A last limitation of the method was that it was very labor intensive, which may limit its uses. This may have also limited the accuracy of content overlap and discrepancies identified; however, the relatively high kappa scores demonstrated a good inter-rater reliability, and therefore accuracy. *Abraham et al.* proposed a semi-automated method of assess content similarity in handoffs, but the approach used in this study focused more on syntactic rather than semantic similarity(126).



#### 3.3.4.2 Conclusions

This study examined the impact of an electronic handoff tool on communication and shared mental models of fellows, residents, and nurses. Handoff Tool had no impact on conversation interactivity nor content overlap, but implementation lead to a significant decrease in the rate of questions asked during handoffs and an increase to the rate of information discrepancies among team members. The decrease in the rate of questions asked during clinical handoffs may be explained by Handoff Tool and the associated ease of information sharing and gathering prior to the verbal handoff. Overall Handoff Tool appeared to have limited impact on clinical teamwork. Future work should elucidate the variations of information discrepancies rates among different clinical teams.

### 3.4 Study 2: Information Sharing Workflow

#### 3.4.1 Introduction

Electronic handoff tools were implemented as a way to improve handoffs. A few studies have demonstrated their efficacy in improving the data quality of written handoff notes(146) and completeness of verbal handoffs(47), and reducing patient harm(16,17). Given the nature of these tools, new research has found that electronic handoff tools are increasingly being used by non-intended users to gather information and supplement information sharing among interdisciplinary(28,29). For example, *Vawdrey et al.* showed that non-physician clinicians (nurses, pharmacists, social workers, etc.) accounted for 60% of active users in a resident handoff documentation tool(32). Similarly, Schuster et al. reported that the physician handoff tool was integrated into the daily workflow of non-physicians(29).

While this phenomenon has been observed a few times in the literature now, challenges remains to electronic handoff tools being used as a primary communication tool between interdisciplinary team members. Previous studies found that resident-based electronic handoff tools do not fully provide the information necessary for interdisciplinary team members(29). Furthermore, *Rosenbluth et al.* found that printed handoff notes from electronic handoff tools had only between a 3 to 4 hour half-life (162). Lastly, handoff notes are another form of clinical documentation, and *Hripscak et al.* shows that interdisciplinary team members generally do not read the notes of other roles, particularly, nursing notes(163).

At the same time, many questions in understanding how electronic handoff tools are used by interdisciplinary teams remain. While previous studies have highlighted that non-intended use of electronic handoff tools exists, there is still a general lack of understanding how these tools are being used by interdisciplinary teams, and why electronic handoff tools are being adopted by other roles. The goal of this study was to understand how Handoff Tool is used to enable information sharing among interdisciplinary teams. Specifically, this study looks why and how frequently handoff notes are updated in Handoff Tool, and whether there is a relationship between the frequency handoff notes are updated and viewed in Handoff Tool.

The research questions for this study are:

- Are there systematic temporal patterns to updating and viewing Handoff Tool?
- Why are handoff notes in the Handoff Tool updated?
- Are more frequently updated notes also viewed more frequently?
- Are the frequencies of Handoff Tool updates and/or views related to clinical units?

### **3.4.2 Methods**

#### *3.4.2.1 Handoff Tool*

Handoff Tool is a custom-designed module included as part of the commercial EHR system (Sunrise Eclipsys), originally designed for resident physicians in adult internal medicine. In general, residents, or resident like providers, such as physician assistants and nurse practitioners, use Handoff Tool to write handoff notes for each patient. Other team members can view the handoff note through the Handoff Tool. The Handoff Tool has nine free-text boxes: Active Issues, Consult Notes, Contact Info, Coverage To Do List, Discharge Planning, Hospital Course, Notes and Comments, Patient Summary, and Primary To Do List. The Handoff Tool also provided the functionality to create a printed handoff note that included structured data, such as clinical laboratory results and medication information for each patient. Furthermore, all users could choose to print a cover sheet that summarized select patients.

#### *3.4.2.2 Audit log data set description*

The audit log data for Handoff Tool during October 2013 was extracted, cleaned, and analyzed. The audit log captured all instances when Handoff Tool was viewed and updated at Columbia University Medical Center campuses of NewYork-Presbyterian Hospital. Information collected when handoff notes were viewed included the clinician's username, the clinician's provider role, the patient's unique identifier, the unit the patient was at the time the note was viewed, and a timestamp of when the clinician accessed the tool. Information collected when handoff notes were edited in the Handoff Tool included the clinician's username, the clinician's provider role, the patient's unique identifier, the unit the patient was at the time the note was viewed, a

timestamp of when the clinician accessed the tool, and which free-text box of Handoff Tool was updated.

#### *3.4.2.3 Update/View Frequencies Grouping*

To analyze the frequency handoff notes were updated and viewed, the number of updates and views were tabulated for each handoff note in twelve hour cycles, which reflect the general shift work patterns of clinical work identified in previous studies(164). Thus, the unit of analysis was any patient's handoff note for a single shift. Day shifts were defined as occurring between 7am and 7pm, and night shifts were defined as occurring between 7pm and 7am. Updates were defined as whenever a field of the handoff note in the Handoff Tool was changed regardless of the author. Views were counted as whenever the handoff note was accessed in the Handoff Tool by anyone on the clinical team except the primary author of the handoff note. The primary author of the handoff note was defined as the resident who updated the tool the most during a particular shift. After the frequency of updates and views for each single shift handoff note were tabulated, each note was sorted into one of the nine groups defined in Table 3.8. Each of these nine categories could be grouped into one of three higher-granularity categories: handoff notes with the same category of updates and views during a single shift, more updates, or more views. These categories can be found in Table 3.8. as well labeled as "matched cases", "more updates", and "more views".

**Table 3.8** Activity level coding schema

	<b>None (0 Updates)</b>	<b>Minimal (1-2 Updates)</b>	<b>Frequent (3 or More Updates)</b>
<b>None (0 views)</b>	<b>A</b> (matched case)	<b>D</b> (more updates)	<b>E</b> (more updates)
<b>Minimal (1-2 views)</b>	<b>G</b> (more views)	<b>B</b> (matched case)	<b>F</b> (more updates)
<b>Frequent (3 or more views)</b>	<b>H</b> (more views)	<b>I</b> (more views)	<b>C</b> (matched case)

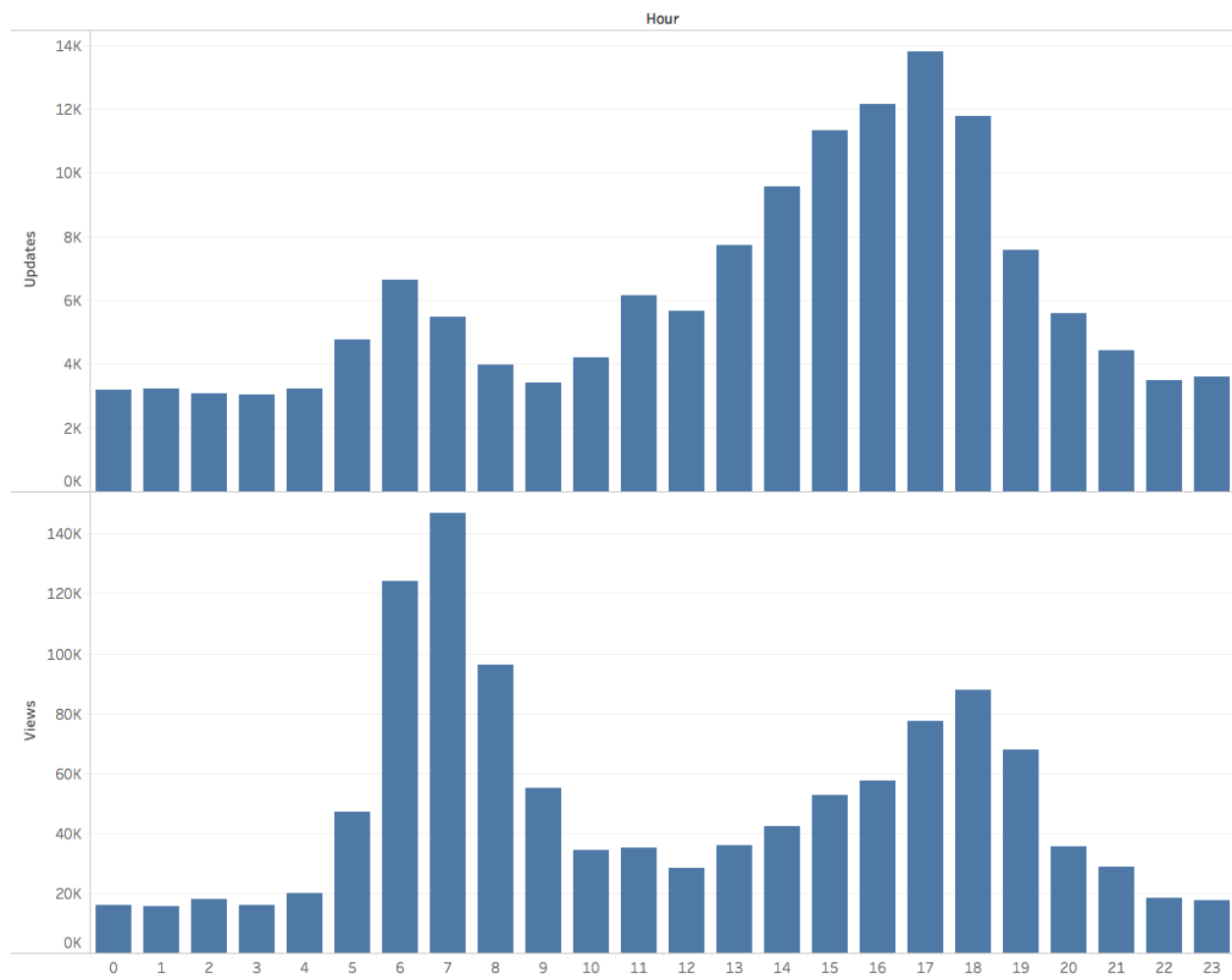
To discover temporal trends of when Handoff Tool was updated and viewed, the hour value for the timestamp of every action (update or view) was extracted and plotted. To test if there was an association between the frequency handoff notes were updated and viewed, each unit of analysis, a handoff note during a particular shift, was sorted into one of three categories based on the frequency of Handoff Tool updates. An ANOVA test was used to test whether there was a significant difference in the frequency of views between the three categories of Handoff Tool update frequencies.

#### *3.4.2.4 Qualitative interviews*

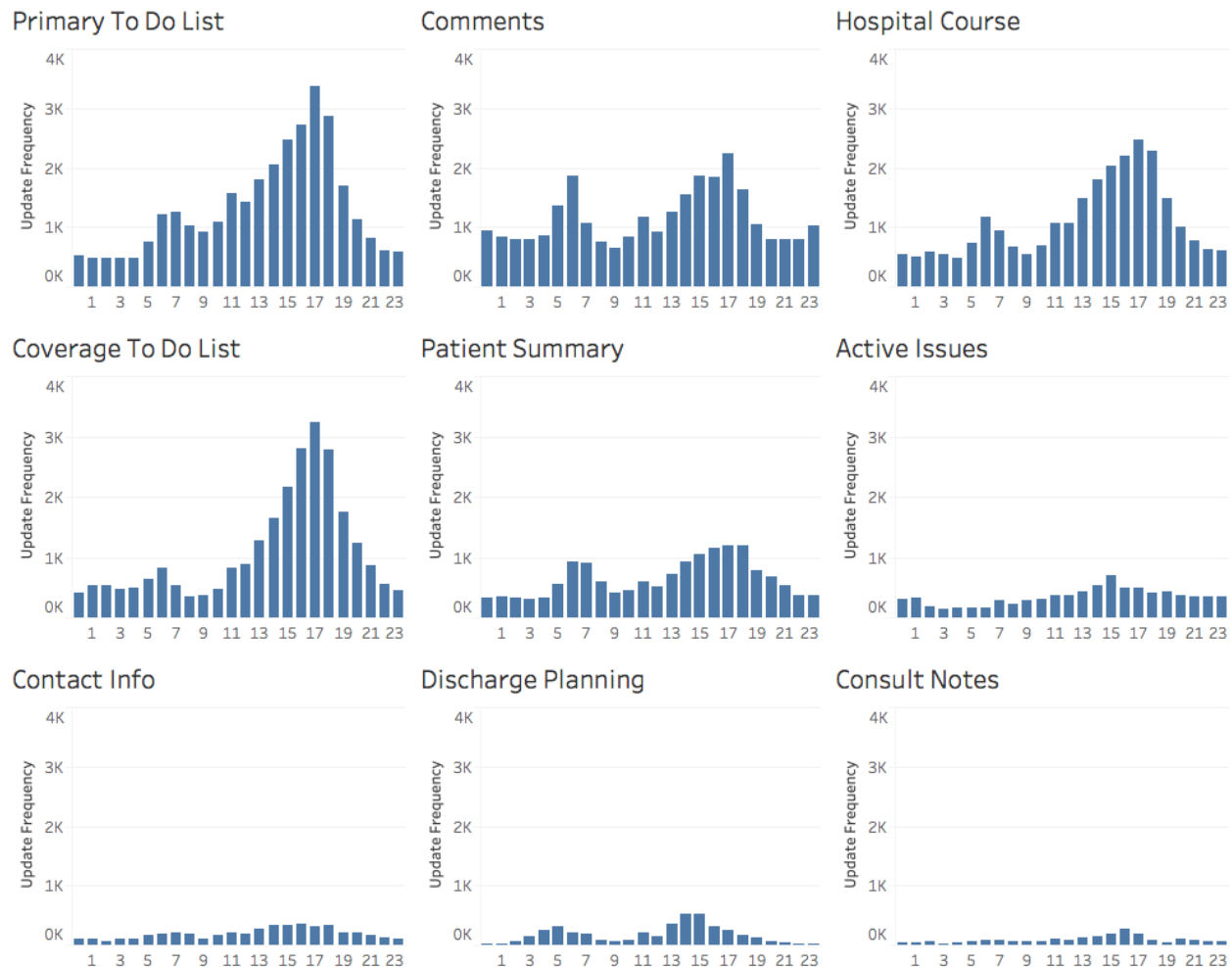
Seven semi-structured interviews were conducted with clinicians from different clinical units of the hospital. Three residents and one attending from the pediatric intensive care unit were interviewed. Two residents in adult internal medicine residency, and one nurse practitioner from the pediatric bone marrow transplant unit were also interviewed. All interviews were selected by convenience sampling. All providers were consented prior to the interview. The interviews were audio-recorded and professionally transcribed.

### 3.4.3 Results

Figure 3.3. describes the total frequency the Handoff Tool was accessed for updating and viewing handoff notes throughout the month of October. The figure shows that Handoff Tool is used throughout the entire day, rather than just shortly before and after expected clinical handoff periods. The most frequent hours of Handoff Tool usage for either updating or viewing notes are during clinical handoff periods. Figure 3.4. provides a breakdown of the frequency each free-text box was updated throughout the month of October. The figure shows that the Primary and Coverage To-do Lists text boxes were updated the most frequently, followed by the Comments and Hospital Course text boxes. The Consult Notes and Discharge Planning text boxes were the least updated text boxes. While these last two text boxes were not as frequently updated as others, this does not guarantee that no information was recorded. The information could simply be static information and therefore not frequently updated.



**Figure 3.3** Frequency of updates (top) and views (bottom) per hour in the Handoff Tool

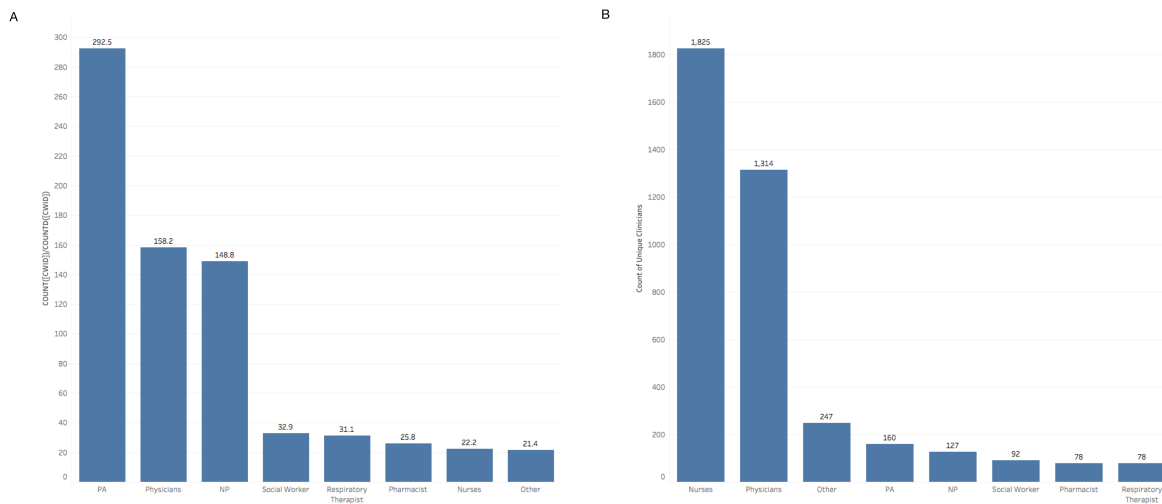


**Figure 3.4** Frequency of updates per hour for each text box in the Handoff Tool

Figure 3.5.A. shows the total frequency the Handoff Tool was viewed by different care provider roles normalized by the number of unique clinicians in each role. Figure 3.5.B. shows the total number of unique clinicians in each role. The results show that physician assistants had the highest rate of the Handoff Tool views after normalization, followed by physicians and nurse practitioners. Because the Handoff Tool was designed for residents, it seems logical that physicians and roles are similar to residents have the highest rate of use. The figure also shows some use by team members who do not play a resident-like role, such as social workers, physical therapists, pharmacists and nurses. Figure 3.5.B. shows a slightly different perspective.



This figure shows that a large sample of nurses use the Handoff Tool, albeit just not as frequently as some other roles.



**Figure 3.5** (A) Frequency of views by clinical provider role and (B) total count of unique clinical providers utilizing the Handoff Tool per role

To approximate the effect of patient severity on the use of the Handoff Tool, the Handoff Tool updates were stratified by the clinical unit where the patients were on at the time of the update (Table 3.9). The table shows that 8 out of the 15 (53%) locations were associated with intensive care units. While not definitive, this finding shows that updates to the Handoff Tool is at least partially associated with patient severity.

**Table 3.9** Top units with highest percentage of frequently updated notes

Unit	Services(s)	Percent
CH 3 NORTH ENDO	Pediatric Endoscopy	96.67
<b>B09T</b>	<b>Pediatric Cardiac Intensive Care Unit</b>	<b>87.37</b>
<b>H5CT</b>	<b>Adult Cardiothoracic Intensive Care Unit</b>	<b>84.44</b>
<b>B09S</b>	<b>Pediatric Intensive Care Unit</b>	<b>76.17</b>
M8GS	Adult Medicine/Cardiology/Neurology	71.42
<b>M4SI</b>	<b>Adult Surgical Intensive Care Unit</b>	<b>67.29</b>
<b>MICA</b>	<b>Adult Medical Intensive Care Unit A</b>	<b>65.61</b>
<b>B09N</b>	<b>Pediatric Intensive Care Unit</b>	<b>60.56</b>
AICU	Adult Intensive Care	60.16
B06T	Pediatric Cardiology/Neurology/Pulmonolgy	59.70
M5CC	Unknown	58.38
B04T	Pediatric Medical/Surgical/GI/Transplant	57.42
<b>B08S</b>	<b>Pediatric Medical/Surgical/GI/Transplant/ Neonatal Critical Care Unit</b>	<b>55.34</b>
<b>M5CT</b>	<b>Adult Cardiothoracic Intensive Care Unit</b>	<b>54.46</b>
BXXX	Pediatric Emergency Medicine	52.11

\* Bolded rows signify intensive care units

Table 3.10. shows the distribution of single-shift handoff notes that fell into each of the 9 categories of note update and view ratios. Analysis of the three higher-level categories showed that note usage was most likely to be matched, with similar updates/views frequency (Table 3.11). Among handoff notes in this group, the Handoff Tool was most likely to either be not utilized at all or updated and viewed frequently.

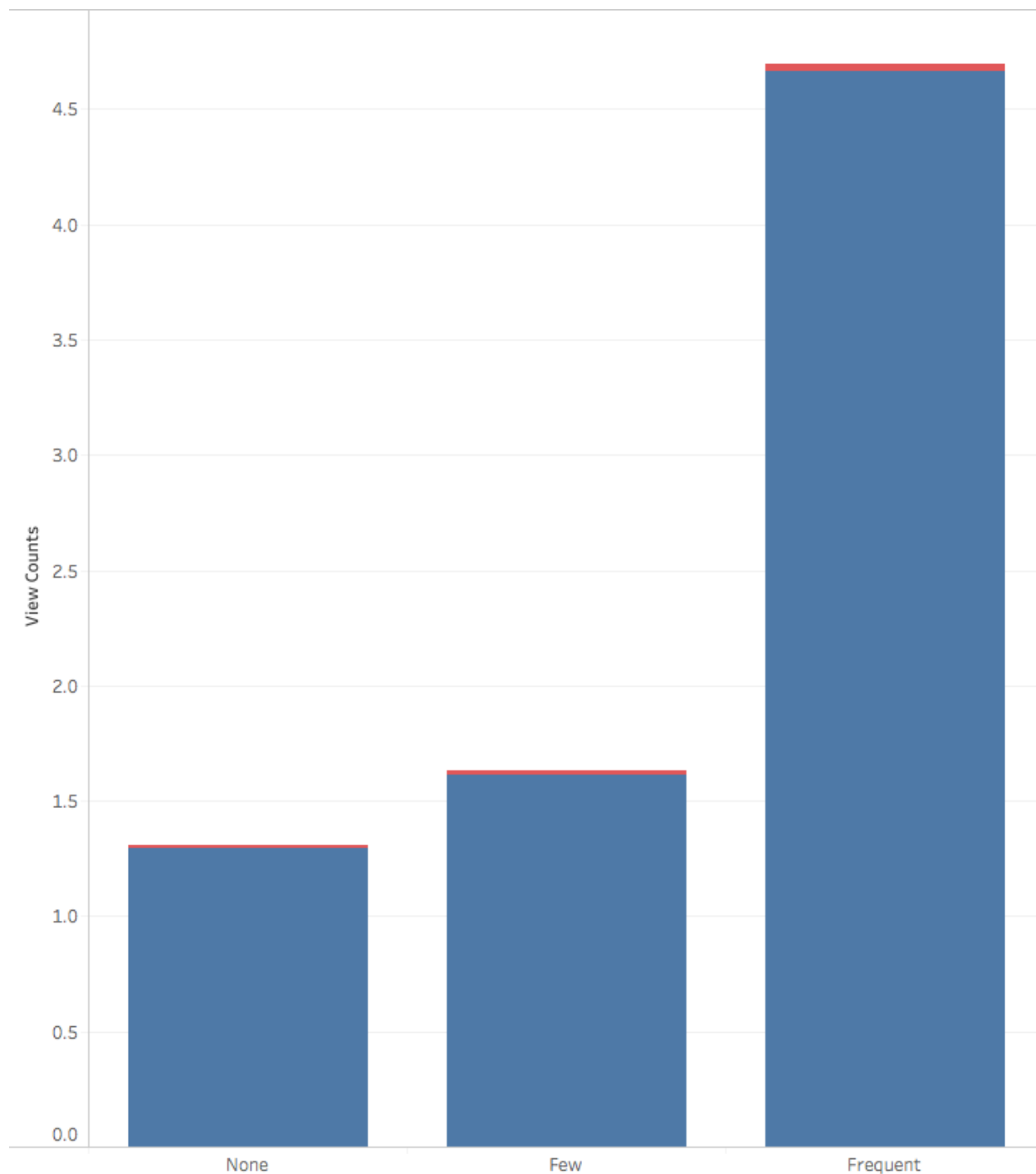
**Table 3.10** *Percentage of notes by each note activity level*

Updates/Views	None (0 Updates)	Minimal (1-2 Updates)	Frequent (3 or More Updates)
None (0 Updates)	18.10%	12.19%	4.10%
Minimal (1-2 Updates)	19.60%	8.73%	6.98%
Frequent (3 or More Updates)	7.08%	6.50%	16.71%

**Table 3.11** *Percentage of notes by matched/mismatched categories*

Matched	Mismatched (More Updates)	Mismatched (More Views)
43.44%	23.20%	33.10%

Figure 3.6 shows the average and standard error (red bar) of handoff note views for each handoff note update frequency bin. The ANOVA test showed that the note update frequency bins had significantly different frequency of views ( $F = 12893$ ,  $p < 2.2 \times 10^{-16}$ ). Post-hypothesis testing using Tukey's HSD test showed that all three groups are significantly different from each other ( $p < 2.2 \times 10^{-16}$  for each instance). The largest effect size difference in note viewing frequency was between single-shift handoff notes that were never updated and single-shift handoff notes that were updated three times or more. There was also a large effect size difference in note viewing frequency between single-shift handoff notes that were updated once or twice and notes that were updated three times or more. While statistically different, the effect size difference between single-shift handoff notes never updated and notes updated once or twice was relatively small.



**Figure 3.6** Average view count and standard error for each update group

The qualitative interviews provided much insight into log data findings. In all seven interviews, participants explained that they primarily wrote handoff notes to provide information for night coverage teams and consulting physicians. Despite this, Participant 3, who worked in the

pediatric intensive care unit, explained *“Yeah. I’m usually – I usually keep track of things on my paper printout but then probably like three or four times a day I would do that [updating Handoff Tool throughout the day].”* This quote showed that despite the primary function of the Handoff Tool notes being written for handoffs, some residents in the hospital still maintained the information up to date. This explains why the audit logs revealed that the Handoff Tool was updated throughout the day, rather than just a few hours before and after morning and evening handoffs.

Other participants provided one explanation for why users sought to keep information in the handoff note updated in the Handoff Tool, rather than just on paper. Participant 7, who worked in the pediatric bone marrow transplant unit, expressed that bedside nurses frequently read the participant’s handoff notes at the beginning of the shift and often asked the participant follow-up questions based on the handoff note. Participant 1 who also worked in the pediatric intensive care unit, explained *“If we have down time and I have time to update during the day, I do that as well just so it is up to date for anyone who refers to it, and sometimes I know our nurses refer to it and the attendings refer to it.”* These quotes show that clinicians who author notes in the Handoff Tool can be aware that other team members seek information in the Handoff Tool. Additionally, at least one clinician interviewed (Participant 1) directly attributed efforts to keep the information in the Handoff Tool updated because of an awareness that others were referring to information found in handoff notes.

In contrast to the residents and the nurse practitioner in pediatric settings, Participants 5 and 6, who were adult internal medicine residents, described little to no interactions with other clinicians because of information in the Handoff Tool. Similarly, they also expressed little

awareness of other clinicians on the team reading their handoff notes. Comparing these experiences to experiences reported by the other interview participant, suggests that unit practice variations impacted the use of handoff note for information sharing. However, Participant 6 explained that *“I think that if there had been a greater awareness of others reading [the handoff note], it would have been updated more.”* This suggests that awareness of other’s actions acts as a positive feedback loop in regards to updating. However, the audit log analysis showed that some, but not many, internal medicine units did have a high level of frequently edited notes. These findings together show that there may be some awareness of using the Handoff Tool to share information among internal medicine residents; however, this awareness may not be as widespread as units where clinicians are colocated. Expounding further upon the differences in units, Participant 6 explained that ICU teams and general medicine teams operated differently. ICU teams often operated closely, while general medicine teams operated in a more physically diffused manner.

#### **3.4.4 Discussion**

While electronic handoff tools, such as the Handoff Tool, were designed to facilitate clinical handoffs, particularly for residents, previous work has shown that they are increasingly also being adopted as an information sharing tool for interdisciplinary team members(28,29). This study focused on understanding how the Handoff Tool is used from the perspectives of both the note author and the note viewer. The audit log analysis showed continued use, both updating information and viewing information in the Handoff Tool, throughout the day. *Rosenbluth et al.* found that printed handoff notes had a half-life of about 3 hours during day shifts and 6 hours during night shifts(162). The results of this study showed that handoff notes

were updated about 2.4 times during day shifts and 1.7 times during overnight shifts in Handoff Tool. Based on the *Rosenbluth et al.* estimates, the results of this study show that information in the Handoff Tool was more likely to be up-to-date than printed versions of handoff notes that were never updated by hand. Consistent with *Vawdrey et al.*, this study found that nurses were the largest group of users of Handoff Tool(32). However, this study contributes further understanding by showing that some smaller user groups, such as social workers and pharmacists who are far fewer in size, had roughly the same rate of viewing information in the Handoff Tool as nurses. This finding affirms the findings of previous work in suggesting that electronic handoff tools can be a valuable source of information for clinicians of different care provider roles. While more usage of the Handoff Tool certainly appears to be associated with units that have higher severity patients, this does not take away from the finding that the Handoff Tool may be a good platform for residents or resident like roles to share information with other interdisciplinary team members without requiring direct communication.

This study revealed that there is alignment in updating/viewing practices for electronic handoff notes. The Handoff Tool notes were more likely to be matched in updating and viewing practices than mismatched. The high prevalence of matched usage suggests that clinicians appear to have an understanding of whether other interdisciplinary team members are using the Handoff Tool as an information source. The notes that were updated three or more times in the Handoff Tool also had significantly more views over the course of a single shift than notes that were updated less frequently. Furthermore, the difference in the average number of views between the three bins of the Handoff Tool update frequency shows that the relationship between updates to Handoff Tool and views of the Handoff Tool is not entirely linear. The

qualitative interviews showed that updates to the Handoff Tool and views of the Handoff Tool acted as a positive feedback to stimulate the each other. The non-linear trend is important in this context because it suggests that frequent editing has a larger effect on viewership. In other words, the data implies a stronger positive feedback effect on viewing information on the Handoff Tool when it is also updated more frequently. These two analyses together show that clinicians readily co-develop an awareness of the Handoff Tool as a tool to help share information, but also this practice seems to be well established in some units, as the notes that were frequently updated were significantly and dramatically more frequently read.

This awareness and therefore increased use of the Handoff Tool for information sharing appears especially true for intensive care units, where patients' conditions often change rapidly throughout a shift, and where members of patient care teams must work in close alignment with each other. Previously, researchers used the term social translucence to describe the degree of awareness between individuals about their respective practices in social settings. According to *Erikson et al.*, being aware of intentions and actions of others helps individuals to maintain a high degree of cohesion and coordination(165). This study suggests that across the hospital, and particularly for intensive care units, electronic handoff tools are contributing to social translucence among members of patient care teams. Residents update their notes more frequently knowing that others refer to these notes for updated patient information, and other members of the teams view these notes more frequently with the expectation that they are updated. Handoff notes at our institution are carried over from the previous version and act more like to a single note that evolves over time, rather than traditional notes. Because of this difference, alignment of note update and view frequencies is an important indicator that note



writers are providing and note viewers are reviewing updated information. However, the study also showed that there are cases when these practices are not aligned, suggesting an opportunity for improvement. For example, currently, clinicians are not informed of new updates to handoff notes that might indicate important changes in patients' conditions. One possible solution to this limitation is the addition of an RSS-style subscription of handoff note updates that could help clinicians more reliably disseminate new patient information and maintain higher level of awareness within patient care teams. It is critical to note that these solutions are meant to be a replacement for face-to-face communication, but rather these solutions should be viewed as providing opportunities to help share information asynchronously when synchronous communication is difficult or not desired.

### 3.5. Discussion

The overall goal of the Aim I was to explore the impact of electronic handoff tools on different measures of clinical teamwork, such as patterns of verbal communication and shared mental models, as well as on teams' information sharing activities.

During the first study, verbal clinical handoffs between fellows, residents, and nurses were analyzed to evaluate the impact of implementing the Handoff Tool on teamwork measures. The results showed that implementing the Handoff Tool significantly reduced the number of questions asked during clinical handoffs; this result was particularly pronounced for nurses, even though the Handoff Tool was not designed with nurses as primary users of the tool. These results may suggest that the Handoff Tool has become a common information source for clinicians during preparation for handoffs; as a result, the clinicians had lower information needs during the verbal handoff, and asked fewer questions. The study also showed a

considerable, but not significant increase in the rate of information discrepancies between content of verbal handoffs of different care providers on the same patient care team. These findings suggest that the Handoff Tool may have limitations as an interdisciplinary communication tool. While it was adopted by clinicians in different roles, it was not specifically designed to support interdisciplinary communication. This suggests a need for new tools that are designed with a greater awareness of shared information needs amongst team members.

The second study focused on studying information sharing between interdisciplinary team members by using a combination of audit logs and qualitative interviews. The results of the study showed that information in the Handoff Tool was updated by residents not only in preparation for the actual handoff, but throughout their shifts; similarly, it was viewed by others at different times throughout their shifts. Furthermore, handoff notes that were frequently updated were also more frequently viewed by other care team members.

Together the two studies highlighted continuing lack of tools providing explicit support for interdisciplinary communication; as a result, clinicians on patient care team continue to rely on written documentation as a method for sharing information. The first study, in addition to others on shared mental models and overlapping information needs(30,31,153), showed that clinical teams team members have overlapping and individualized information needs during clinical handoffs. However, results from that study also revealed that the Handoff Tool did not provide all of the necessary information to maintain shared mental models, as demonstrated by the increase in information discrepancies after the Handoff Tool was implemented. This result has two implications. First, it suggests that tools to support interdisciplinary information need to support both the needs of the team and individual users. Currently, the Handoff Tool is

designed to primarily support resident clinical handoffs. This is revealed by both the interviews in the second study and by its design intent(32). While interdisciplinary team members may find the information useful, it does not completely satisfy their information needs(29). Data from the shared mental model analysis showed that nurses had many unique information needs during clinical handoffs from residents and fellows. Therefore, future tools should seek to satisfy both the shared information needs of the team, in addition to the current goal of supporting the information needs of individual clinicians.

Based on the results of the second study, future tools to help teams communicate also need to help team members develop an awareness of each other and their respective clinical work. While few tools exist in healthcare that help clinicians develop this awareness, much work has been done outside of healthcare(166). Within healthcare, there have been a few isolated efforts to passively improve organizational awareness by using screensavers on computer displays to show updates on patient flow and IT updates(167). However, *Antunes et al.* defined several aspects of workplace and organizational awareness(168). The past efforts, such as those by *Adams et al.*(167), have focused primarily on workplace and work environment awareness, yet other types of awareness, such as location awareness, which addresses the understanding of team member location, distance, and orientation are missing in the previously mentioned screensaver methods(168). The results of the second study in this aim show that understanding a team member's location may be an important aspect of understanding who belongs on the patient care team. Therefore future tools to support developing team member awareness should target a more comprehensive set of awareness in the workplace as defined by *Antunes et al.*(168).

## Chapter 4: Aim II - Identification of Challenges Information Needs

### During Discharge

#### 4.1 Introduction

The findings from the studies in Aim I demonstrated that clinicians often appropriated tools designed to facilitate physician handoff to support interdisciplinary team information sharing. However, these tools did not always lead to the desired improvements in communication and teamwork between providers. These findings led me to argue for the importance of designing new informatics tools that specifically focus on promoting and supporting interdisciplinary communication and information sharing within teams rather than simply re-appropriating existing solutions.

This aim focused on information sharing during patient discharge rather than clinical handoffs for several reasons. First, while Aim I studied the impact of the Handoff Tool on different aspects of clinical teamwork, the shift-change handoff is not an interdisciplinary process in the local setting where these studies were conducted. In contrast, patient discharge is an interdisciplinary process; as a result, it calls for tools that promote and facilitate interdisciplinary communication and information sharing. Second, while the Handoff Tool has already been widely adopted by clinicians in different roles at the NewYork- Presbyterian Hospital (NYPH), there exist no currently available tools to support communication and information sharing during patient discharge. To address these current gaps in supporting interdisciplinary communication during patient discharge, this aim focuses on understanding information needs during patient discharge with the goal of providing design recommendations

for developing novel solutions to support communication and information sharing during discharge.

Patient discharge is the process of safely transitioning the patient out of the hospital(11,12).

Patient discharge is a complex process that requires many overlapping and interdependent activities and necessitates coordinated work of an interdisciplinary team(14). Each team member has a unique set of responsibilities in regards to patient discharge. For example, physicians are in charge of determining when a patient is medically stable and is ready to be discharged; nurses are responsible for providing education regarding continuous care at home, among other things; pharmacists explain when patients should take prescribed medications(169). Because the discharge process has so many activities, it is important that all team members communicate effectively to remain synchronized (64).

Because of the complexity of discharge, delays in the process can occur and lead to the delayed discharge. Delayed discharge is a common success measure for the discharge process; it is defined as a prolonged stay in the hospital for no medical reason(42,113,170). Discharge delays are especially notable because they negatively impact both the patient and the healthcare organization. For the patient, discharge delays have been shown to increase the rate of hospital-acquired infections(41), among other negative consequences. For the healthcare organization, there is a loss of revenue when providing care for patients who have a delay in their discharge(42). These negative consequences demonstrate the importance of avoiding discharge delays.

While many aspects of the patient discharge process have been extensively studied in an effort to improve the process, there are still gaps in understanding interdisciplinary communication

between care providers during patient discharge in the inpatient setting. Communication and information gaps between inpatient and outpatient providers have been extensively studied(171-173), but these studies did not investigate interdisciplinary communication within the inpatient setting. *Bergstrom et al.* found that discharge plans were sometimes not fully shared between care team members in the inpatient setting{Bergstrom, 2008}; however, there is still a lack of understanding regarding what information is needed by each care team member during discharge and how that information is shared. While some have shown that interdisciplinary rounds provide key opportunities for interdisciplinary teams to communicate and improve patient outcomes, these conversations are generally short and occur only periodically(104-107). Furthermore, none of these studies discussed the types of information that were shared between care providers and which clinicians were involved in information sharing. Therefore, the first study in this aim seeks to understand information needs of various care team members during the discharge process outside of interdisciplinary rounds.

The second study sought to create a data-driven classification of discharge delays. Previous literature explored different approaches to identifying factors and patient characteristics associated with discharge delays; however, there has been relatively little effort in capturing or documenting reasons for discharge delays at the process level. This gap leads to a lack of understanding regarding critical process issues that influence discharge and may contribute to discharge delays. Previous efforts to categorizing discharge delays used expert panels in a pediatric setting(174). However, there have been few efforts to create empirically derived classifications of discharge delays. Moreover, despite the increased availability of clinical and

billing data, there has been a lack of published literature on using alternative data sources for characterizing and categorizing discharge delays.

## 4.2 Information needs of interdisciplinary team members during patient discharge

### 4.2.1. Introduction

Patient discharge is an important team-based process(14). The ability to share information during patient discharge between team members is crucial(14), but there are currently few tools to support sharing of information pertaining to discharge among members of interdisciplinary teams. Several studies found gaps in verbal and written communication between members of clinical teams during patient discharge(12). While interdisciplinary rounds have been shown to improve interdisciplinary communication during discharge(104-107), the scheduled and periodic nature of rounds do not facilitate ad-hoc information sharing. *Jenkinson et al.* found that discharge summaries often lacked crucial information for follow-up care (175), which is associated with poor patient outcomes(176). In summary, while there are many potential ways to improve interdisciplinary communication, all of them have limitations. To overcome the challenges and limitations of current solutions, new tools should be proposed with the sole intent to support interdisciplinary information needs during patient discharge from the hospital.

However, before such tools to support information sharing can be developed, the information needs of care team members must be understood. Yet there is a lack of systematic research focusing on clinician information needs during the time of discharge. Therefore, the main goal of this study was to understand and identify information needs related to patient discharge.

The research questions in this study are:

- Who participates in the discharge process and what are their information needs?
- How do information needs evolve over the course of the discharge process?
- How do current EHR tools support information sharing and information needs?

#### **4.2.2 Methods**

To identify care providers, their functions during discharge, and their information needs, a mixed-methods study was performed involving audit log analysis of information viewed in the EHR systems, SCM and iNYP, and qualitative interviews with different care team members. The audit log analysis and the qualitative data collection and analysis were performed in parallel. SCM is the local installation of the Allscripts Sunrise product, a commercial, vendor EHR. It is a comprehensive EHR, allowing clinicians to place and view orders, medications, and laboratory results, and create and view clinical documentation, among other tasks. iNYP is a homegrown electronic tool for viewing data available in the EHR; iNYP includes custom interface to access clinical data as well as various clinical data dashboards. iNYP can be accessed through SCM or separately through a web browser.

##### *4.2.2.1 Setting*

This study was conducted in a single medical cardiac unit, Milstein 5 Garden South, at NewYork-Presbyterian Hospital/Columbia University Medical Center (NYPH/CUMC). NYPH provides care to a diverse population, including minorities, low-income and elderly. Patients are hospitalized in this unit with heart failure, coronary heart disease, valvular heart disease and arrhythmias. This unit encompasses multiple physician teams and contains a single unit-based care



coordination, social work, and bedside nursing team. The patients in the unit were treated by one of four physician teams, and each of the physician teams treated patients on other units as well.

#### *4.2.2.2 Audit log data collection*

All EHR usage logs for SCM and iNYP were collected for patients discharged from Milstein 5 Garden South from between 01/2016 and 06/2016. The SCM audit log data captured some but not all orders, views of different user interface tabs within SCM, such as Handoff Tool or Results, views of some specific action such as copying or viewing PHI, and instance of copy forward from the resident discharge summary. Each data entry also included the user ID as well as timestamps (but no durations) and the patient the record belonged to. iNYP data included many details related to what data type was retrieved along with user ID, timestamps (again no durations) and the patient the record belonged to. Examples of iNYP data types include lab results and cardiology notes.

Analysis of the data was limited to only the last 24 hours prior to the patient's discharge. Discharge time was based on the EHR data of when patient left the hospital. The last 24 hour time period was chosen to increase chance that data access was in relation to discharge or discharge planning, and qualitative analysis showed that last 24 hours was primary time for discharge related activities.

#### *4.2.2.3 Audit log data analysis*

Frequently accessed data types were identified for iNYP data for each provider group. For SCM, the frequently accessed data types were limited to those associated with viewing information, excluding data types associated with, for instance, documenting information. Provider groups

were pre-identified during qualitative interviews. To identify frequently accessed data types, the data types were filtered for types that were accessed for either at least 25% of all unique patient visits (different from unique patient count) or at least 25% of all unique clinicians in the provider group used it. While one patient can have more than one visit, this is not considered a bias because we wanted to base the analysis on most used information. So even if one patient had multiple visits during the study period, each visit was included separately to provide a representative sample of the patient case load and disease variation.

The first analysis was used to determine what data types and user interfaces were commonly accessed by clinicians in different roles, and whether there were similarities and differences in access between these roles. After the frequently accessed data types and user interfaces were determined, the frequency with which each data type or user interface was utilized by a care provider role was tabulated and normalized by the number of distinct care providers in that respective role.

The second analysis was performed to identify temporal patterns of EHR usage. After the frequently accessed data types for each of the systems for each provider type independently were identified, the counts of each access to a particular data type were tabulated per hour. If a data type was used frequently by multiple provider types, the frequency was calculated for each provider type independently per hour.

#### *4.2.2.3 Qualitative data collection*

The data collection included 1 focus group and 8 qualitative interviews with 3 different provider types: 5 physicians (3 residents, 2 attending physicians), 3 bedside nurses, and 4 care coordinators (2 nurse care coordinators, 2 social workers). Interviews focused on 3 areas: 1)

characterization of the discharge process and clinicians' functions during the discharge process, 2) identification of barriers to successful and timely discharge, and 3) identification of information sources related to discharge, particularly outside of the EHR (to complement the EHR audit log data). The 5 physicians and 3 bedside nurses were individually interviewed.

The 4 care coordinators participated in a focus group, and the same question guide was used. The moderator (SJ) prompted the group with questions related to each of the three previously highlighted research areas, and the clinicians each answered individually. Research participants in the focus group were continuously given opportunities to give differing or dissenting opinions during the focus group. All interviews and the focus group were audio-recorded and professionally transcribed.

#### *4.2.2.4 Qualitative data analysis*

In the first phase, the transcripts of the interviews and the focus groups were analyzed using open coding to identify basic categories of findings. Open coding was done collaboratively by SJ and LM in a personal meeting that involved reading the transcript and discussing emerging categories. After the initial coding scheme was developed, SJ continued coding independently, periodically meeting with LM and discussing changes to the emerging coding scheme. After the open coding was completed, SJ and LM reviewed resulting categories, and used axial coding to identify high level themes and their dimensions.

#### **4.2.3. Results**

Analysis of the audit log was focused on three areas: 1) identifying common information needs that occur during patient discharge based on clinicians' access to EHR in the hours prior to

discharge, 2) mapping information needs evolution over the trajectory of a patient discharge, and 3) studying temporal patterns of information needs between providers.

Physicians, nurses, physician assistants, and social workers all had more than 10 distinct users in each provider role for both SCM and iNYP usage. Other care providers, such as physical therapists, while playing a crucial role in the discharge process, did not have enough interactions with the EHR to be meaningfully captured by the audit log data. Therefore, all other providers were excluded from analysis.

#### *4.2.3.1 Unique and overlapping information needs*

The audit log analysis showed that interdisciplinary team members had both shared and unique information needs during the discharge process. Table 4.1. shows a breakdown of data types from iNYP that are common and unique among different clinicians. The analysis shows that care providers (physicians, nurses, and physician assistants) shared a greater overlap on retrieving medical information, particularly cardiology information. Social workers on the other hand uniquely retrieved non-clinical patient information. Table 4.2., similarly, showed a breakdown of the user interfaces and select actions from SCM that are overlapping and unique to team members. In SCM, most of the different interface tabs were frequently accessed by all of the clinicians on the team; however, only social workers viewed non-clinical patient information frequently. Physicians and physician assistants sought out medication information with higher frequency than all the other care providers. Lab values and documentation were among the data that was frequently viewed by all members of the care team.

***Table 4.1*** *Overlapping and unique data types accessed in iNYP*

Data Types Accessed	Physician	Physician Assistant	Nurse	Social Worker
/ptdata/clinical/webcise	✓			
Main Lab Summary	✓			
PtListEclipsys	✓			
Sum Type Lab Main	✓			
Rad	✓			
Summary	✓			
Trend	✓			
Clinical	✓			
Lab	✓	✓	✓	
Card	✓	✓	✓	
XANote	✓	✓	✓	✓
XAADM			✓	
/ptdata/profile/profile				✓
Webcise	✓	✓	✓	✓
/ptdata/summary/summary	✓	✓		

\* Check marks indicate that 25% or more of that provider type accessed the data type for that row in iNYP.

**Table 4.2** *Overlapping and unique frequently accessed SCM user interfaces*

	Physician	Physician Assistant	Nurse	Social Worker
Tab: Flowsheet	✓	✓	✓	✓
Tab: Documents	✓	✓	✓	✓
Tab: iNYP	✓	✓	✓	✓
Tab: Handoff	✓	✓	✓	✓
Tab: Orders	✓	✓	✓	✓
Tab: Patient List	✓	✓	✓	✓
Tab: Dose Hx	✓	✓		
Tab: Data Vis	✓			
Tab: Patient Info				✓
Tab: Patient List	✓	✓	✓	✓
Viewed Document List	✓	✓	✓	✓
Core Document Detail Viewed			✓	
PHI: Discharge Instructions Exported			✓	
Prescription Printed	✓	✓		
PHI: RxWriter Exported	✓	✓		
Pull Set Values Viewed	✓	✓	✓	✓
DR Documents Details Viewed	✓	✓	✓	✓
Flowsheets Viewed	✓	✓	✓	✓
Patient Info Viewed				✓

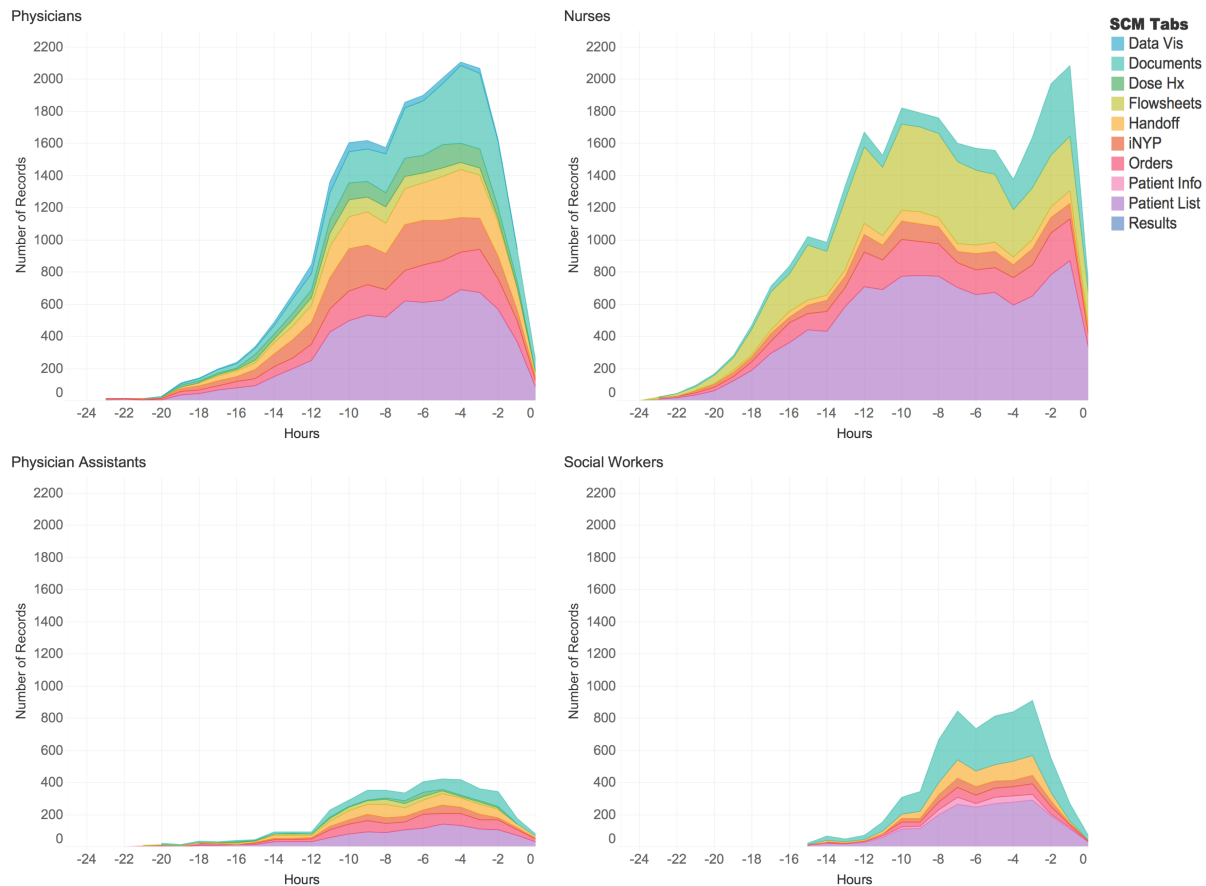
#### *4.2.3.2 Temporal patterns of information access*

Figure 4.1 shows the temporal patterns of interfaces accessed in SCM by clinicians in each clinical role. In general the frequency of information access continued to increase leading up to the time of discharge before dropping in frequency. The figure shows that access to different types of information peaked at different times of the pre-discharge period and also that these peaks varied for different clinicians. For instance, among nurses, the peak utilization of the Flowsheet tab prior to patient discharge was between roughly 8 to 12 hours prior to patient discharge; however, the peak utilization for most other SCM tabs was closer to roughly 1 to 2 hours prior to patient discharge. This finding demonstrated that the use of the Documents tab rises dramatically in the final hours of the patient's stay. This effect could be found for users in other clinical roles as well, particularly for the Documents tab, although it was not as pronounced. However, the granularity of the audit logs does not show what specific type of note (i.e. progress note, discharge summary note, etc.) was edited. The increase in usage of information in the Documents tab does suggest that clinicians heavily rely on free-text notes to complete their discharge tasks. Figure 4.2, which displays the total use of SCM for each clinical role colored by the SCM interface, shows that different team members reached the peak SCM usage during different times of the patient discharge process. For instance, physicians had peak usage of SCM between 3 to 5 hours prior to patient discharge, while nurses had peak usage in the last 2 hours of the patient's hospital stay.



**Figure 4.1** Use of different SCM Tabs grouped by provider roles. The usage counts are calculated on an hourly basis and normalized by the count of distinct providers within each role.

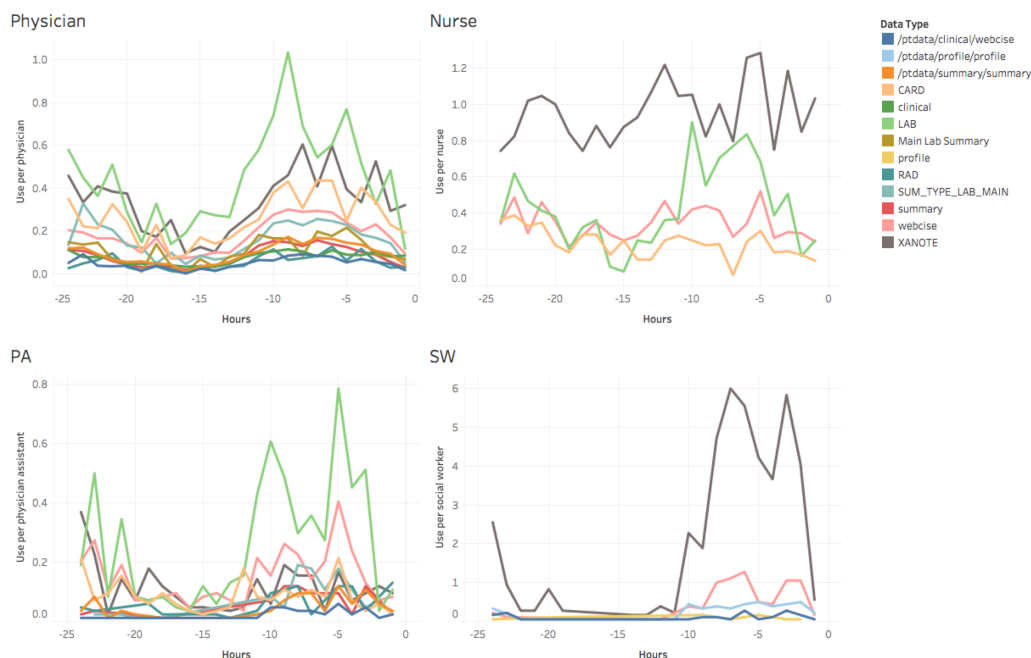




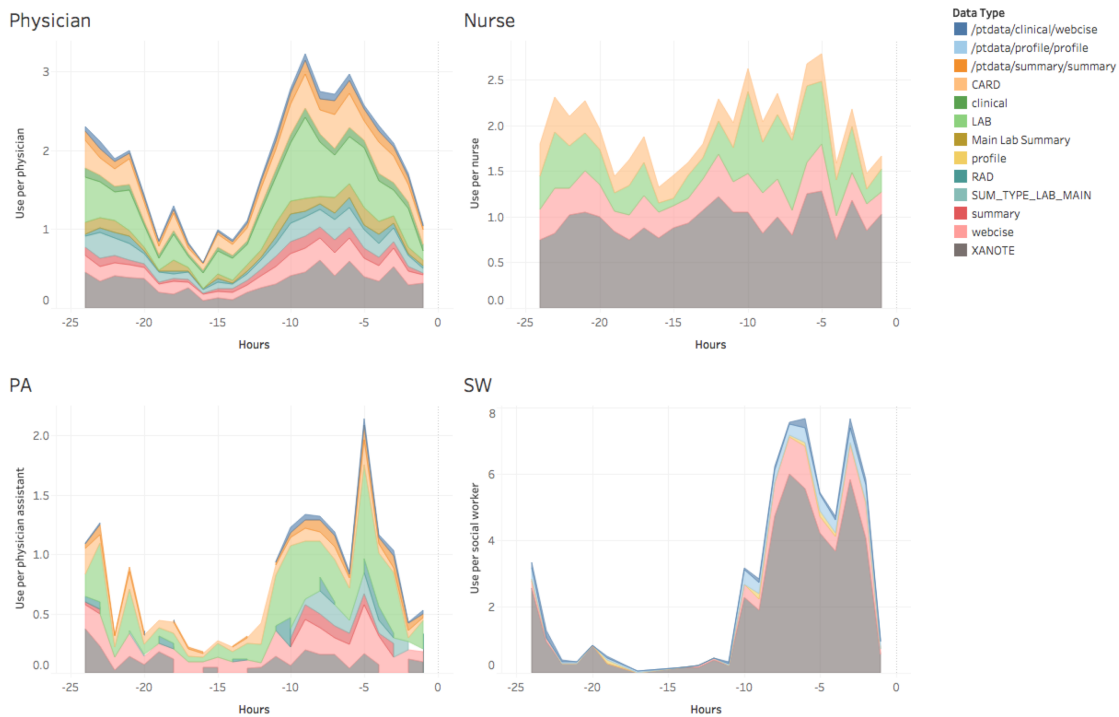
**Figure 4.2** Total use of SCM Tabs grouped by provider roles

Figure 4.3 shows the temporal distribution of clinicians' access to different types of data in iNYP by clinicians in each clinical role. Some of the patterns of trends identified by the SCM audit logs were consistent in describing iNYP usage as well. For instance, in iNYP the results again showed that there was an evolution of information needs during the day of discharge. Among nurses, the frequency of viewing lab results, cardiology related data, and general WebCIS views followed the same trend between 12 to 24 hours prior to patient discharge. In the latter part of the pre-discharge time (12 to 0 hours prior to patient discharge), however, the frequency of viewing lab results dramatically rose at around the 11-hour mark, while the use of cardiology

related data and general WebCIS views remained the same or slightly dropped. Based on iNYP usage, while physicians, physician assistants, and social workers all had clear peaks in iNYP usage prior to a patient's discharge from the hospital, nurses appeared to have more consistent usage of iNYP throughout the 24-hour period prior to a patient's discharge. Comparing the peak usage among each of the care providers, physicians' usage peaked the earliest, at between 8 to 10 hours prior to patient discharge. Physician assistant had peak usage at around 5 hours prior to patient discharge, and social workers had two peaks between 6 to 8 hours pre-discharge, and then another peak in iNYP usage around 2 hours prior to patient discharge.



**Figure 4.3** Frequency of data types viewed by provider roles. The usage counts are calculated on an hourly basis and normalized by the count of distinct providers in each role.



**Figure 4.4** Total frequency of data viewed by provider roles.

#### 4.2.3.4 Task Dependencies

Analysis of the qualitative interviews revealed a few key challenges related to information sharing and information needs during the discharge process. The first challenge was the difficulty in coordinating timely task transitions due to the need to manage both concurrent and sequence-dependent tasks during patient discharge. The second challenge was that the EHR did not contain all the information necessary for safe discharge.

During interviews, care team members described several tasks and activities that need to occur before a patient can be discharged. Some of these activities occurred concurrently; however, other activities occurred in sequence. The interviews revealed that the completion of the

discharge summary by a resident was a critical task in the discharge process, which triggered a transition in discharge responsibilities and tasks. Much of the work residents and social workers or care coordinators had to complete occurred prior to the resident completing the discharge summary. Examples of these tasks include residents performing medication reconciliation and scheduling follow-up appointments, while in parallel, social workers and care coordinators screening patients and identifying appropriate post-discharge care facilities to help residents ensure follow-up care and care continuity. After the discharge summary was finalized, nurses then began physically preparing the patient for discharge. As nurse 1 explained, *“as a discharge summary being done that’s when we also know that it’s in movement... once that’s (discharge summary) complete then we are ready to know that it’s a definite discharge.”* The challenge in having team members work in parallel and sequentially was that care providers could not easily inform each other of what tasks were completed. Therefore, some actions had to be completed sequentially, which often caused delays because team members could not easily coordinate their work. As a care coordinator summarizing the situation explained, *“So the doctors have to have a full completed discharge summary. Drop the discharge order, then the nurses can pick up the case. But the barrier, the blockage is that the nurses don’t know when that discharge order went into (SCM).”*

#### *4.2.3.5 Unmet information needs*

Team members, but especially residents, all identified unmet information needs. Physicians focused on two areas of information needs. The first unmet information need was the availability of a comprehensive medication list that included medications beyond what is available in the EHR. As resident 3 highlighted, *“So for instance, like I had a woman come in for*

*the weekend on both medications for hyper and hypothyroidism. It didn't really make sense and the family couldn't really answer to the question, pharmacy wasn't open. And she was discharged yesterday without any...*" This quote demonstrates that, often times, patients and their family were unable to provide sufficient information related to a patient's medication list to the clinical team. To make matters worse, this information was often not available or difficult to find in the EHR. The lack of a clear medication list complicated the resident physician's medication reconciliation process. A second area of unmet information needs was the lack of medical information outside of the hospital. As resident 1 explained, *"basically the hardest thing is finding out what they do in the outpatient setting... the transition from inpatient to outpatient can't happen unless I know all those..."* This quote shows that information related to the patient prior to the hospital stay was difficult to obtain but crucial to the discharge process.

#### **4.2.4. Discussion**

The audit log analysis showed that interdisciplinary team members had both overlapping and unique information needs as evidenced by their access to the EHR during patient discharge. This suggests that new informatics solutions for supporting interdisciplinary teams during patient discharge should have the ability to highlight overlapping information needs, while also showing information that is seemingly unique to a single role. Displaying information that is critical to only some members of the care team, for instance, information related to medications, which was frequently accessed by physicians and physician assistants, is still critical to other care team members, such as nurses. Results from the qualitative analysis show that nurses require an understanding of the patient's post-discharge medication needs in order to provide timely and comprehensive education to their patients. Currently, nurses rely on a

patient education order to start this education process; an information display that summarizes important medications to nurses, in addition to physicians and physician assistants, may increase their shared understanding of the patient's medical and educational needs.

The second general finding from the audit log analysis showed that information needs for each clinician evolved over the course of the last 24 hours prior to a patient's discharge. This finding suggests that information displays should have the context of when the patient is anticipated to be discharged from the hospital and display information in reference to this expected discharge time. For instance, the Documents tab of SCM plays an increasingly important role for nurses as the time of patient discharge approaches but is not frequently accessed earlier on the day of discharge. Therefore, making that information more readily available closer to the time of discharge may be important.

The third general finding was that the frequency with which clinicians viewed EHR data was generally linked to the distribution of tasks related to patient discharge identified by the qualitative interviews. For instance, analysis of the audit logs showed that physicians reached their peak usage first compared to the three other roles studied. Analysis of the qualitative interviews confirmed that during patient discharge, physicians' activities related to discharge often preceded those that were allocated to nurses.

Finally, the study showed that while EHR was an important source of information necessary for facilitating the discharge process, it often lacked critical information needed by clinicians to perform their duties. Furthermore, the EHR in this study appeared to be ineffective in helping team members coordinate and share information about the progression of the discharge process with each other. Future EHR tools developed to aid in the discharge process should

help clinicians monitor completion of tasks, and raise their awareness of upcoming tasks in the discharge process.

A key limitation in this study is related to limitations of audit logs in identifying information needs of clinicians during the discharge process. For example, the audit logs only tracked when a tab in SCM was accessed, and did not track why it was accessed (viewing data or adding/updating data) or for how long it was accessed. Therefore, not all of the tab access counts in SCM can be positively ascribed to viewing data; however, other data do allowed triangulation of the findings based on the SCM audit logs. Because iNYP only allows for data to be viewed, the audit logs for iNYP show parallel upticks in data access as the time of discharge approaches. Furthermore, clinicians can view notes from SCM from the iNYP system (XANOTE), which gives further support to the finding that documentation data becomes more important as the time of discharge approaches. Finally, the audit logs of SCM do not provide enough granularity to identify what data elements are being viewed; therefore, the findings are only based on what SCM Tab is being accessed.

### 4.3 A classification to describe discharge delays

#### 4.3.1. Introduction

Discharge delays are a critical issue, which negatively affects healthcare organizations and patients(41,42). Studies tracking the rate of discharge delays reported rates ranging between 4%(42) and 50%(115); however, most studies reported discharge delays between 25% to 40%(43-45). Other studies of discharge delays have shown that a number of patient characteristics and non-patient factors are associated with discharge delays, such as decline in

function(43), and being elderly(44). However, these studies do not reveal the nature of why discharge delays occur, and current literature examining discharge delays from a process perspective is sparse. Notably, there exists one example of a classification of discharge delays; however, this study focused on pediatric discharge delays and was developed using an expert panel rather than constructed empirically(174).

At NewYork-Presbyterian Hospital, social workers documented discharge delays using a documentation tool that had both structured and unstructured fields for capturing information about the patient's discharge delay. The structured documentation was a list of critical discharge delays identified by the senior managers, and the unstructured fields were free-text boxes that allowed for social workers to document any other relevant information about the patient's discharge delay and explain the reasons in their own words. A review of the data by senior managers found that the structured data collected did not match free-form descriptions of the same delays. Analysis of the data showed that users primarily documented details of a patient's discharge delay in free-text rather than in structured fields, thus challenging the validity and accuracy of structured entries. For instance, if a patient could not be successfully placed into a sub-acute rehabilitation center due to insurance issues, social workers often selected the structured documentation option associated with sub-acute rehabilitation centers and documented in the free-text area that there was an issue with the insurance company.

This study sought to examine free-form comments and explanations for discharge delays entered by social workers and create an empirical, data-driven classification of discharge delays. The motivation to use a data-driven approach was based on the assumption that creating coding categories based on retrospective data would create a classification that was



more in line with how social workers thought about discharge delays. A data-driven approach to developing the classification was achieved by using the free-text data portion of previously documented discharge delays. Because of the variability of patient discharge across different settings, this analysis focused on adult patient discharge, which had never previously been categorized in the literature before.

#### **4.3.2. Methods**

All discharge delay documentation between 01/2015 through 09/2015 from NYP/CUMC Adult units were queried from the CDW. Documentation data was divided into structured and unstructured fields. To capture the discharge delay data, social workers were asked to select a reason for discharge delay from the available list, and were then given an option to use free-form data field to accompany their structured entry. To develop the classification, all of the narrative explanations (unstructured discharge delay documentation) were extracted from the dataset.

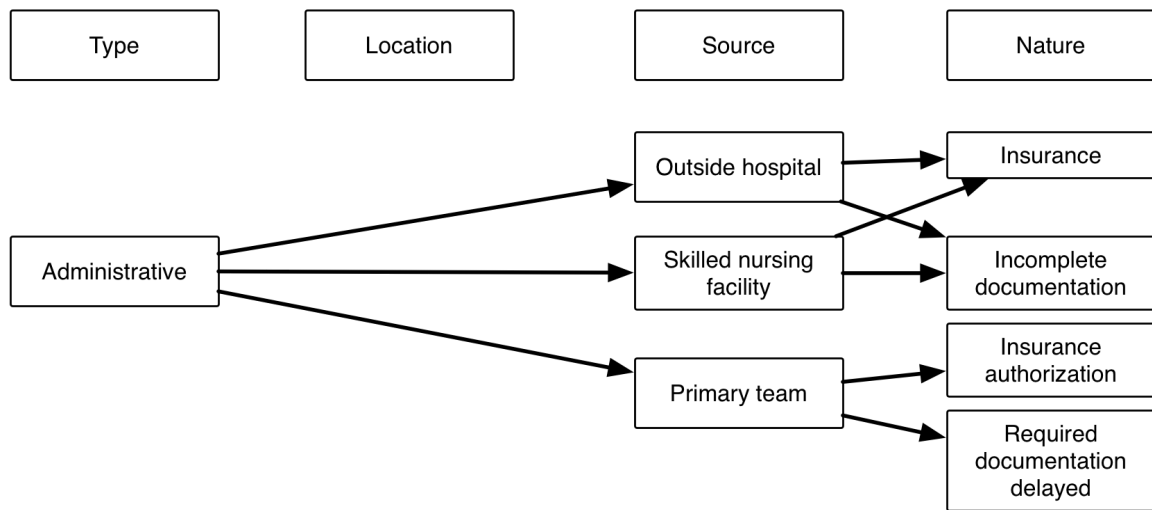
One hundred unstructured discharge delays were extracted from the dataset and used as an initial sample to develop the classification of discharge delays. Three coders, two informaticians and 1 nurse researcher, co-coded the data together to create the initial classification. Then a second set of one hundred unstructured discharge delays was extracted, and coded by each of the three coders independently. Discrepancies in coding were discussed and resolved.

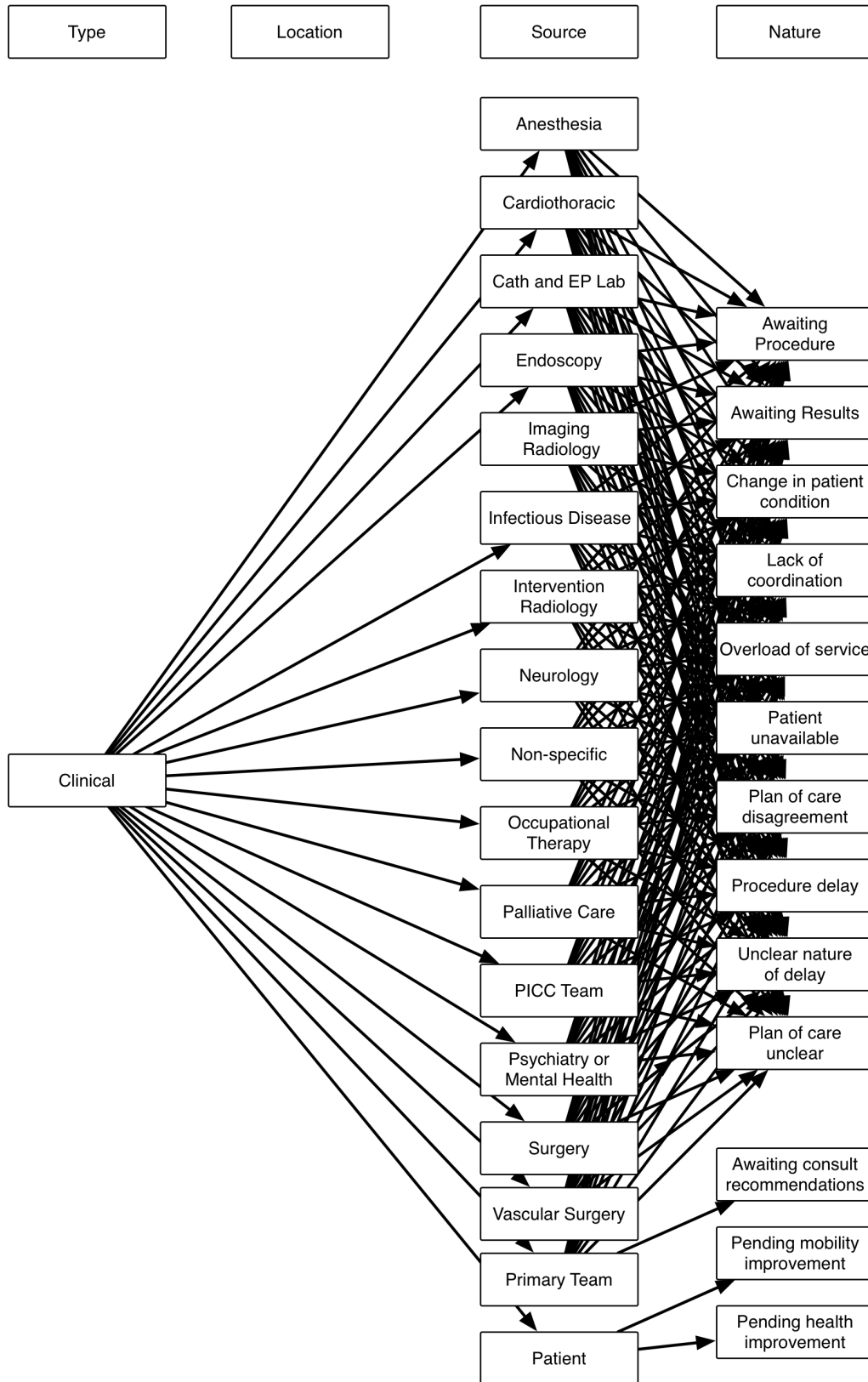
A third set of one hundred unstructured discharge delays was extracted from the dataset and coded by myself and a new nurse researcher. The new nurse researcher was experienced in qualitative coding but been blinded to how the classification was developed. A brief co-coding exercise was performed between myself and the new researcher, after which, both the nurse

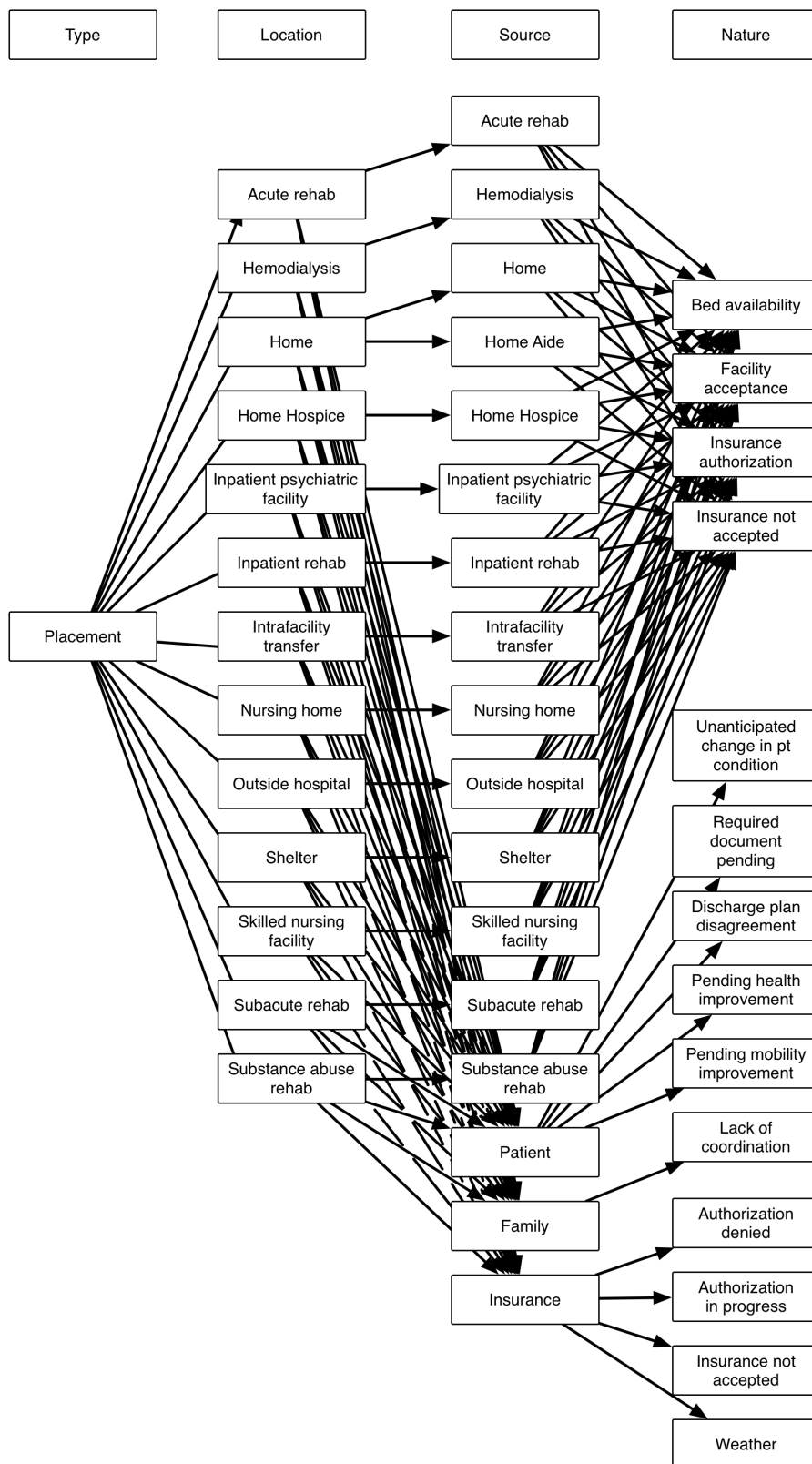
research and myself independently coded the one hundred discharge delay explanations. NVivo was then used to calculate the inter-rater reliability for each level of the classification.

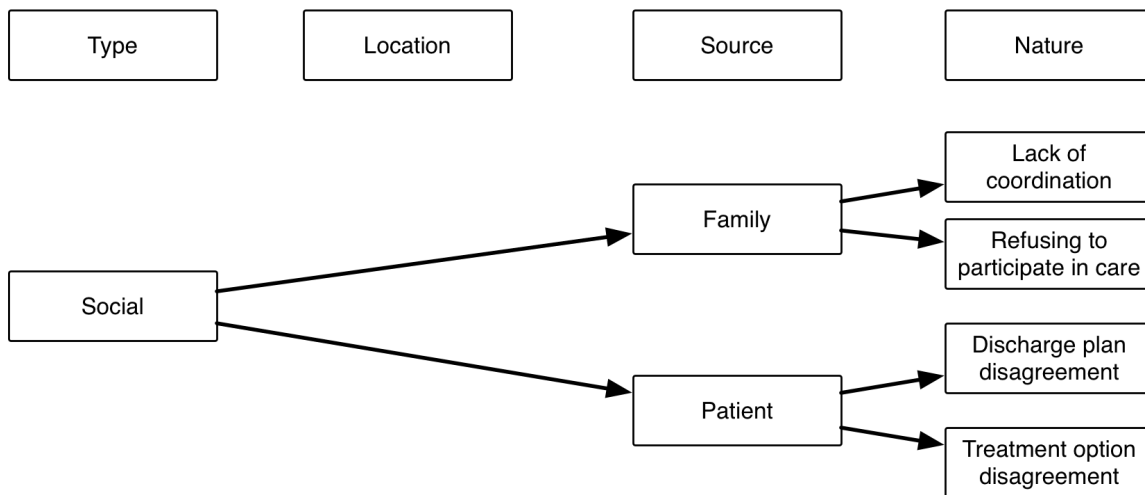
#### **4.3.3. Results**

Overall there were 2,173 unstructured discharge delay documents from 1,964 unique patient visits in the dataset. A four-dimension classification was created to categorize discharge delays (Figure 4.5). The first dimension of the classification is the discharge delay type. The type of delays aims to capture the high level reason a discharge delay occurred, such as a patient's preferences ("social") or external facility issues ("placement"). The second dimension of the classification is the discharge delay location. The location of the delay is the post-hospital location where the delay can be attributed. It should be noted that only discharge delays related to the placement discharge delay instance were classified with the location dimension. The third dimension of the classification is the source of the delay, which is the individual or team who were perceived to have caused the delay. Examples of this dimension include members of the immediate care team, a consultation team, the post-acute care facility, or even the patient and his/her family. The last dimension of the classification is the nature of the delay. This dimension is the fine grain categorization of the delay, such as a delay because a procedure or study for the patient had to be conducted.









**Figure 4.5(A,B,C,D)** Discharge delay classification. The arrows indicate the hierarchical property of discharge delay classification.

One noteworthy characteristic of the classification is that there are dependencies between some dimensions. For example, discharge delay types dictate whether a discharge delay location has a meaning. Specifically, placement delay instances dictate that discharge delays have a location dimension instance, but social delay types do not have a location dimension instance. Some source dimension instances had dependent nature dimension instances. As an example, when the immediate team is the source of delays, some corresponding nature of delay instances include waiting for documentation or trying to file appropriate documentation. However, when the consulting team is the source of delays, some corresponding nature of delay instances include the consulting team pushing a procedure or study back or being overloaded with other consultation cases. This characteristic of the classification reflects how sometimes the dimensions had a hierarchical nature.

A second noteworthy characteristic is that some location dimension values shared a grouping of source dimension instances, and some source dimension instances shared a group of nature dimension values. For instance, all of the different types of locations shared the same base of source dimension instances, such as family, patient, and insurance. The different facility source instances also shared a collection of different nature dimension values, such as the facility having accepted the patient or having a bed available for that patient. Another example of a situation in which different source instances had many overlapping nature dimension values is the different consulting teams, such as radiology and imaging or surgery, and the corresponding nature dimension instances, such as when the consult team delayed a scheduled procedure or study (procedure delay) or when the consult team was unable to add in a patient to the schedule (awaiting procedure). This characteristic of the classification reflected the phenomenon that patients often times experienced the same nature of delay but due to different sources of delay. This characteristic was identified after multiple patients in the data set experienced a delay in receiving a procedure but from different consulting teams, such as cardiology and surgery.

In evaluating the classification on its internal consistency, there was a moderate to high kappa between the lead researcher and the nurse researcher. The kappa for the type dimension was 0.76. The kappa for the location dimension was 0.62. The kappa for the source dimension was 0.61. The kappa for the nature dimension was 0.33. Two explanations for the very low kappa score for the nature of delay dimension is that: 1) there were many choices for values among the location, source, and nature dimensions and 2) sometimes patients could experience several reasons for discharge delays simultaneously or experience a series of different

discharge delays. Regarding the first explanation, the classification was operationalized in NVivo such that each source dimension instance had a number of dependent nature of delay instances coders could then select from. In this manner, each instance of the nature of delay instance was selected for very few recorded discharge delays. This operationalization of the classification may have artificially reduced the kappa score. Regarding the second explanation, coders were instructed to select only one discharge delay classification. If multiple discharge delay reasons were identified, coders were instructed to select the classification that they felt most represented the initial reason for the discharge delay, but this required subjective interpretation, which may have contributed to the low consistency between coders.

In the evaluation dataset, the top two most frequent types of delays were clinical and external placement delays. Within the external placement delays, the most frequent locations were from sub-acute rehabilitation facilities. Within clinical types of delays, there were no location dimension values, since the location dimension refers to the post-discharge location. The two most frequent sources of discharge delays were the radiology and imaging tech team and the surgical team. The corresponding nature dimension values for both of those sources were procedure delays and awaiting procedures.

#### **4.3.4. Discussion**

This study sought to develop a classification of discharge delays for adult patients based on free-text descriptions of discharge delays documented by social workers between January 2015 through September 2015. The classification was developed by three researchers inductively coding a small portion of the free-text data. The classification developed describes discharge delays based on four dimensions, delay type, delay location, delay source, and nature of delay.



Evaluation of the classification with an independent nurse researcher showed a moderate to high kappa value for most levels of the classification.

This classification of discharge delays differs from the previous classification of discharge delays in two ways. First this classification is focused on adult discharge delays rather than on those captured for pediatric patients. Comparing the two classifications, there are many overlaps in the discharge delays recorded; however, but there are also key differences. The pediatric focused classification included many details about delays due to the family, which is not surprising, given the role of parents in making decisions regarding care for their children prior to adulthood(174). In contrast, the parts of the classification developed in this study that involve family center largely on either agreement (or lack thereof) with the care or discharge plan and coordinating and supporting the patient after discharge. While the classification developed in this study includes classifications of patient or families disagreeing with either the care or discharge options, there were far fewer classification options for care disagreement than in the pediatric focused classification.

The second key difference between the two classifications is the methodology employed to develop the classification. In *Selker et al.*, the authors used a series of focus groups and panel discussions of physicians and nurses to arrive at the discharge delay classification (174).

However, this approach is based on clinicians' recollection of patient cases, which can be subject to recall bias. Furthermore, clinicians may be biased when discussing discharge delays during focus groups by their perceptions of what discharge delays are common or worth capturing. In contrast the classification developed in this study is based on records that were made in the context of clinical work. While data quality issues are common in clinical data, the

classification developed here is not biased by clinicians' memories of past events. Furthermore, since the data was already collected and only required retrospective analysis, in contrast to the case in *Selker et al.*, the timeline to develop and validate the classification could have been much faster(174). During the evaluation stage, only 10% of the test set required modifications of the classification, primarily linking previously identified nature of delay values to be assigned to new source of delay values.

This study has a number of limitations. First, this study was conducted at a single metropolitan teaching hospital. This may limit the generalizability of the discharge delays identified and categorized to non-teaching hospitals, as well as non-urban hospitals. Furthermore, the frequencies of discharge delays and categories of discharge delays may not generalize to other hospitals. More comparisons need to be made at other healthcare settings to understand the prevalence of discharge delays in general and the different categories of discharge delays.

Second, the data used in this study was collected based on the perceptions of the social worker, and therefore not potentially representative of the entire team. Based on this context, it is possible that other team members may not have felt that a discharge delay occurred despite the social workers' perceptions. A third and related limitation is that during the time when the data was collected, social workers did not have a uniform definition of what constituted a discharge delay. Therefore, some discharge delays could have been mischaracterized based on a universal definition, currently in place, defined at NYPH as part of a larger quality improvement initiative for which this taxonomy was developed.

## 4.4 Discussion

In this aim two studies were conducted to develop a better understanding of the discharge process. The first study focused on understanding information needs of interdisciplinary care providers. The study found that interdisciplinary team members had a considerable overlap in information needs during time of discharge; however, each team member also had role-specific information needs. The study also identified two temporal patterns in information needs. The first pattern was that for a given team member information needs about the patient changed throughout the last 24 hours of the patients stay, with some information, such as documentation, becoming more frequently accessed in the final hours prior to patient discharge. The second temporal pattern identified was that different members of the clinical team appeared to need similar information at different times. Qualitative analysis revealed that information needs were related to the role specific nature of discharge delay activities. Physicians' information needs peaked before nurses' information needs, reflecting the temporal dependency of discharge activities between team members with physicians preparing the discharger order before the nurses execute its. The second study focused on understanding breakdowns in the discharge process, primarily discharge delays. The goal of the study was to develop a classification to categorize discharge delays. The classification was developed using a data-driven approach and based on a small subset of free-text descriptions of discharge delays captured by social workers. After using the classification to code discharge delays in the evaluation set, we identified that clinical delays, particularly delays in completing a procedure or study by a consulting team, and external placement delays, such as sub-acute rehabilitation facilities not accepting patients, were the most frequently identified in the dataset.

Combining the results of both studies together showed that, at times, unmet information needs identified in study 1 could be linked to frequently occurring discharge delays in study 2. One of the unmet information needs that resident physicians expressed in the first study was related to information gaps in the current EHR. One example was information about the patient's post-discharge facility (assuming the patient was not returning home), such as physician contact information at the post-discharge care facility. Another frequently unmet information need that some residents discussed was the difficulty in identifying specific post-discharge care facilities that were associated with frequent difficulties in placing patients in post-discharge care facilities. The discharge delay classification showed that delays were commonly associated with post-discharge facilities. In particular, patients often experienced delays in being discharged because beds at post-discharge care facilities were not available or a specific care facility did not accept the patient's insurance, and thus a new facility had to be identified. Combining the result from both studies show how different unmet information needs can have a negative impact on the discharge process. Many discharge delays occurred because patients could not be placed into a post-discharge care facility in a timely manner; however, residents and other care providers did not have the information to act proactively and help other team members attempt to find a different post-discharge care facility. While the two studies of the aim were not linked, in that the providers who were interviewed in the first study were not the same providers taking care of the patients who experienced discharge delays in the second study, insights from the two studies can be triangulated to highlight the relationship between the lack of information in the EHR and discharge delays experienced by patients.

## Chapter 5: Conclusions

### 5.1 Summary of Work

#### 5.1.1 Aim I

Aim I explored the impact of EHRs, and, specifically, electronic handoff tools on different aspects of teamwork within interdisciplinary patient care teams. The areas of clinical teamwork studied included shared mental models, communication, and information sharing activities. The first study evaluated the impact of a custom-built tool for electronic handoff documentation, the Handoff Tool, on verbal communication during clinical handoffs and on shared mental models within clinical teams. The second study investigated how the Handoff Tool was incorporated into information sharing practices. Specifically, this study focused on investigating the relationship between how frequently information in the Handoff Tool was updated by residents and viewed by different members of their care teams.

The first study found that the implementation of the Handoff Tool did not have an effect on conversation interactivity, but implementing the Handoff Tool was associated with a reduction in the number of questions asked. The Handoff Tool had no effect on teams' content overlap during clinical handoffs, but the rate of content discrepancies rose after implementation of the Handoff Tool. Interviews with physicians showed that the implementation of the Handoff Tool provided an opportunity for clinicians to form a better understanding of their patients prior to receiving a verbal handoff on that patient. This finding provides a plausible explanation for the reduction in questions asked during verbal handoffs after implementing the Handoff Tool.

The audit log analysis in the second study showed that information in the Handoff Tool was updated and viewed throughout the day, rather than just during handoff time. Furthermore, the more the information was updated, the more likely it was to be viewed. This phenomenon was most prevalent among intensive care units, where team members were able to easily observe each other's work patterns and became aware of the norms around using the Handoff Tool for information sharing. Intensive care units also had the highest proportions of frequently updated information suggesting that patient severity increased the likelihood of information sharing through the EHR. Roughly 40% of the information in the Handoff Tool was updated and viewed at the same rate, but 30% of the information in the Handoff Tool was viewed more frequently than updated. This relatively high rate of discrepancies suggests that the Handoff Tool could be optimized to better support clinicians developing an awareness of work practices.

### **5.1.2 Aim II**

Aim II explored the information sharing activities and information needs of interdisciplinary teams during the patient discharge process. Aim II also identified a classification system of discharge delays arising from the discharge process. The first study on information sharing activities and information needs was conducted in the context of a single cardiology unit with a variety of complex, co-morbid patients. The second study used discharge delay documentation from Columbia University Medical Center/NYPH West Campus to develop a classification categorizing discharge delays.

The audit log analysis from the first study showed three properties of information needs among interdisciplinary team members as evident through their access to the EHR. First, interdisciplinary team members have both overlapping and unique information needs during patient discharge.

Second, information needs for each team member change over time. Third, team members have peak information needs at different times of the patient discharge process. Despite the tight coupling between EHR tools and discharge processes, qualitative analysis showed that there were critical unmet information needs, which were not well addressed by the data in the EHR.

The second study used clinician-provided free-form explanations of reasons for discharge delays to develop the first empirical classification of discharge delays in adult care. This study demonstrated the feasibility of using a data-driven approach rather than by relying on expert panels. During the validation stage, discharge delays were most frequently classified as stemming from one of two main issues. The most prevalent issue was placing patients in external facilities, such as a sub-acute rehabilitation facility or nursing home, and the second most prevalent issue were delays in arranging clinical care during the inpatient stay.

## 5.2 Contributions

The work in this dissertation contributed to the field of biomedical informatics in three areas: 1) understanding how EHRs, and particularly tools for electronic documentation impact teamwork, 2) identifying information needs within interdisciplinary teams, and 3) developing new methods for studying clinical teamwork and information needs. These contributions to understanding how EHRs impact teamwork and the identification of interdisciplinary information needs during discharge have implications for the design of future tools to support interdisciplinary communication.

The results from Aim I studies showed that interdisciplinary communication, while important, is not well supported by the EHR. In the absence of well-developed HIT solutions for

interdisciplinary communication, clinicians at times appropriated existing EHR tools to support this communication. However, the results showed that this was a suboptimal approach to facilitating teamwork. The findings suggest a need for new informatics solutions that specifically target interdisciplinary teams and core functions these teams must perform, such as communication and information sharing. One step in supporting interdisciplinary communication is for tools to help team members develop shared norms for sharing information.

Based on the findings from Aim II, future tools supporting interdisciplinary team members during discharge need to have the capacity to display both overlapping and unique information needs during the discharge process. Tools to support clinical teams during the discharge process should ensure that overlapping information needs are easy to find and are shared with everyone on the team. Furthermore, these tools need to be sensitive to the temporal trajectories of a patient's discharge and need to contextualize the displayed information to the progress of the discharge. One possible way to contextualize the information is to prioritize what information is displayed according to what tasks of the discharge process have already been completed. However, this contextualization needs to be balanced with heuristics and design principles to avoid confusion and increase in cognitive burden.

The third contribution of this dissertation focuses on the methodology used to study clinical work and information needs. This dissertation demonstrates the utility of using both qualitative interviews and audit log analysis. Each analytic method has its inherent strengths and weaknesses, which were reviewed in Chapter 2; however, application of a mixed methods approach in this dissertation helped to overcome limitations of traditional studies. Combining different analytical methods and data sources also lead to novel findings that would otherwise



have not been detected using only qualitative interviews or audit log analysis. Using both methods allowed this research to answer questions related to both what EHR tools are being used and for what reasons.

### 5.3 Limitations

#### 5.3.1 Limitations of clinical settings

The first study in Aim I was conducted solely in the pediatric intensive care unit. Because the handoff process is highly variable, the findings about the impact of the Handoff Tool on teamwork may not generalize to other units in the hospital. This is also true for the information needs identified in Aim II. Both audit log and qualitative interviews were only from one clinical unit; other clinical units, even if they are cardiology-related units, may have different information needs during discharge, simply because those units focus on a different subset of cardiology patients. The single-unit studies in both Aim I and Aim II were complemented by studies that spanned the entire hospital; however, this does not guarantee that the findings apply to other settings.

#### 5.3.2 Limitation of audit logs

Audit logs can be an important data source for studying information needs and how clinicians use the EHR. Many of the studies in this dissertation utilized audit logs to study what information clinicians use during clinical handoffs and patient discharge. Indeed, EHRs are often an integral part of many clinical activities, such as placing orders and viewing laboratory results. However, it is important to note some limitations in audit logs as a method for studying clinical work. First and foremost, EHR audit logs can only capture a part of any clinical workflow or clinician

information needs. For instance, during the discharge process, interviews revealed that EHRs were missing much of the information needed for safe discharge, such as information about the patient's primary care providers and certain medication-related information. A second important limitation of EHR audit logs relates to the granularity of the data. While the audit logs for Handoff Tool were very granular, containing a variety of information, including which specific fields of a note were updated or for how long the tool was opened for, other audit logs did not have this data. For instance, the SCM audit logs did not capture granular details about what types of laboratory results were viewed, as compared to iNYP. Furthermore, some data elements, such as when a user logged off of a system, were simply not recorded. Therefore, data availability and data granularity can limit what can be learned about clinical work and information needs when using audit logs. In this dissertation, use of audit logs was paired with interviews with clinicians to try and overcome some of the limitations of audit log analysis. However, this may not solve all problems associated with audit logs, and therefore, many questions related to how clinicians use EHRs still remain and must be answered by other methods.

### **5.3.3 Subjectivity of data analysis**

Several studies in this dissertation relied on qualitative coding, which is subject to the judgement of the research team. In Aim I, the verbal handoffs were qualitatively coded for conversation segments, question types, content overlap, and content discrepancies. While there were rigorous definitions for each concept and co-coding exercises were completed, there were still some disagreements between different research team members during the coding process. Therefore, the frequencies reported for each coded measure could be different if other researchers, particularly clinicians, had qualitatively coded the verbal handoffs. In particular, when coding

content overlap and content discrepancies, other researchers could have disagreed with whether the conversation segments were overlapping or discrepant. In Aim II, there was extensive qualitative coding in the two studies. Qualitative coding of the interview data was performed by both SYJ and another researcher who did not have clinical training. Because the interviews contained technical information about the discharge process, some of the answers to questions could have been misunderstood leading the data to be coded incorrectly. In the second study of Aim II, the discharge delays dataset included clinical nomenclature and abbreviations, which made it hard to deduce their meaning without the appropriate clinical background. Therefore, some of the discharge delays could have been misunderstood during qualitative coding, leading to a non-representative classification. This bias could have repeated itself during the evaluation phase of the discharge delay classification as well.

## 5.4 Future Work

This dissertation gives rise to several areas of future work. The first area of future work would be to operationalize the design recommendations identified in this dissertation. However, a few additional steps need to be taken prior to prototyping a tool based on the recommendations presented here. First, more research should be conducted on identifying information needs of other care team members that were not included in this study, such as physical therapists, who were described as being important care team members during interviews with clinicians but were excluded from the analysis in this dissertation because their EHR usage frequency did not meet the minimum threshold. Second, follow-up studies need to be conducted to determine at a more granular level what information should be included in the tool and how this information should be presented. For instance, many clinical dashboards have been implemented to aid information

retrieval, but these dashboards typically include very specific information, and are often used to visualize numerical data. The results of the studies in this dissertation do not enumerate specific data to be included in such tools, such as particular laboratory values. Therefore, more research is needed to identify information needs at this more granular level. Third, more research is needed in understanding how to present information taking into consideration the temporal aspects of the information needs identified in this dissertation. While the work by *Reddy et al.*, establish some initial directions, more research is needed before a prototype can be built(177).

The second area of future work lies in exploring variations in information needs not just across time but also across different clinical practices. The discharge information needs identified in this dissertation were based on a single cardiology unit; however, it is uncertain whether these information needs are consistent with the information needs of other units. This uncertainty needs to be addressed before any future tool built based on the recommendations from this dissertation is implemented in a hospital or other health system setting. Identifying the relationship between information needs and sources of variation in clinical practice would enable future tools to respond to information needs with greater contextual awareness.

A third area of future work is to explore how EHRs affect other areas of teamwork. Work in this dissertation and others(153,178) focused on shared mental models and communication. Yet shared mental models and communication are just two of several teamwork elements. Another future direction of research should investigate how EHRs can facilitate other aspects of teamwork, such as whether EHRs can help team members redistribute tasks (backup behavior).

Lastly, an important area of future work can include exploration of other methods for studying clinical work and information needs, specifically time and motion studies. This dissertation used

audit-logs and interviews to study information needs, but time and motion is another well-accepted methodology to study clinical work. Future work into comparing the utility of using time and motion studies to study clinical work with qualitative interviews and audit-logs can prove beneficial. Identifying more methods and triangulating clinical work findings between them may open new insights not possible with just using one method.

## 5.5 Conclusions

The goal of this dissertation was to develop a better understanding of how EHRs impact interdisciplinary teamwork. The studies in this dissertation found that interdisciplinary information sharing was desired, but current EHR tools have limited ability to facilitate this information sharing. This dissertation provides several recommendations for the design of future EHR tools for facilitating interdisciplinary communication, such as the need to display shared, as well as provider-specific, information. Furthermore, information needs should be contextualized to the temporal patterns of clinical work, and tools should support the exchange of information between different care providers. These design recommendations were identified using a variety of data sources, and triangulated using different analytic methods. This approach led to a more comprehensive understanding of the functional needs of team-based communication tools. Future work on understanding the impact of EHRs on interdisciplinary teamwork should focus on implementing these design recommendations into early stage prototypes, studying interdisciplinary information needs in other clinical units and work processes, and advancing methods for studying information needs that focus on comparing and triangulating multiple data sources and analytic methods.

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